Wastewater Treatment Options for the Biomass-To-Ethanol Process

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By:
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DRAFT REPORT
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I. Introduction

NREL (National Renewable Energy Laboratory) contracted with Merrick & Company (Merrick) to provide expertise in evaluating Waste Water Treatment Alternatives for various ethanol manufacturing processes. Three Lignocellulosic Biomass-to-Ethanol processes are currently under development by NREL. Each could require different treatment depending on various characteristics of the waste water stream volume and strength. To initiate the evaluation, Merrick met with NREL engineers and scientists in interactive meetings, where the appropriate designs were developed for each of the processes.

II. Waste Water Treatment Processes

Initial designs for the processes showed the potential for large waste water streams which could require extensive treatment systems. During discussions, Merrick showed the trend in the current, similar ethanol and pulp and paper industries to recycle various water streams internally in the process and to reclaim waste water with appropriate treatment to allow recycle. Especially over the past 20 years, once-through water systems have been replaced with minimum discharge systems. This is due not only to the cost of treatment for waste water, but also minimization of environmental impact, cost and availability of makeup water, etc.

In order to guide the selection of the best alternatives for waste water treatment, Merrick created a "map" of potential alternatives and potential internal process changes that would change the volume and strength of the system discharge. The map is shown in Appendix A. The map shows the effects of incorporating various subsystems into the process to minimize waste water generation. A few of the important aspects considered were:

- Elimination of combining all or most waste waster streams into one grand glop for simultaneous treatment. Previous flow schemes routed most waste water streams to a single Waste Water Tank. From this tank water was sent to treatment and then part of the treated water was recycled to the process. By selecting waste water streams which can be recycled individually upstream of treatment the treatment systems become much smaller and overall plant efficiency is greatly increased. Since some waste water streams are cleaner than others, it is better to do minor treatment of the relatively cleaner streams to allow reuse or recycle within the process. This both lowers the volumes of waste water and makeup water and also minimizes the treatment costs for the easily treatable streams.

Also, the objective of waste water treatment is to concentrate contaminants into a relatively small stream, leaving the major stream sufficiently clean for reuse or discharge. If a waste water stream is already somewhat concentrated, it will cost more to re-concentrate the contaminants if it becomes diluted due to mixing with less contaminated streams. Combining the centrifugation of the stillage with evaporation is advantageous in optimizing the recycle.

- Centrifugation of stillage, after the first stage of evaporation, removes the easily recoverable solids before they are combined with any other stream. Combining the streams would make the solids recovery more difficult and expensive. The recovered solids can be used as fuel or sold as byproducts rather than requiring treatment.

- Evaporation of stillage/centrate (the second and third evaporation stages are downstream of centrifugation) using heat integration with the distillation section of the process. The heat available in the required ethanol distillation section would otherwise require extra cooling (water).

Using these and other recycle options, two developments significantly minimized the size of the waste water treatment systems.

1. NREL developed with another contractor an integrated water recycle design intimately associated with the distillation system design. ***Both centrifugation and evaporation were incorporated into the design.***

2. Merrick simultaneously evaluated the application of four alternatives to treatment with various degrees of recycle. Merrick specifically evaluated:
    1. Evaporation (and Incineration)
    2. Stream Discharge
    3. Land Application
    4, Discharge to a Publicly Owned Treatment Works (POTW).

The result is shown in Appendix B, which gives the costs to accomplish treatment of waste water without the improvements listed above (centrifugation and evaporation). As can be seen, the cost for treatment of the full volume of waste water is prohibitive.

Therefore, ***Merrick and NREL reduced the stream volume to that which could be expected from maximization of recycle, evaporation and centrifugation within the process.*** The flow scheme for water and reuse is shown in Appendix C. The waste water system now has significantly reduced flow, making onsite treatment easily achievable with conventional treatment systems.

Below is an explanation of the fully developed systems available for the past 10-20 years to treat these “high strength biologically treatable” streams. In actuality, the current sizing and strength of ***the waste water streams for the three NREL processes are all within the same typical treatment methodology: Anaerobic Treatment followed by Aerobic Treatment.*** Appendix D shows the reasons for application of these treatment steps as developed by industry.

III. Evaporator Syrup Disposition

The concentrate or syrup from the evaporator can be sent to the boiler directly or to the anaerobic digester. Merrick assumed that the syrup could be sprayed or mixed with the lignin cake and sent to the boiler as fuel in a first option. If the evaporators use all of the waste heat in the distillation section the syrup is predicted to contain 7.5 to 8% solids. Using a heat of combustion for the syrup solids of 8000 BTU/lbs. the syrup will have a negative heating value in the boiler. The syrup must be concentrated to about 12.5% solids for a break-even heating value.

The second option would be to send the syrup to the anaerobic digester. The digester and all downstream equipment becomes larger including the aerobic unit but this is somewhat offset by the production of more methane gas (boiler fuel) in the anaerobic digester.

Appendix G contains the comparison that was conducted. Various configurations of the anaerobic/aerobic units were considered and judged based on simplicity (ease of operation and maintenance) and cost. The decision was to burn the syrup at approximately 7.7% solids with the lignin in the boiler.

IV. Flows and Strength of the waste:

The stillage from the three processes qualifies as “high-strength” waste. At the beginning of the project, the CODs and BODs (Biological and Chemical Oxygen Demand) of each process were presented by NREL based on testing simulated stillage (Pinnacle 1998; Evergreen Analytical 1998) and an initial mass balance. These initial estimates are presented in Table 1.

Table 1

PROCESS	FLOW (Kg/hr)	COD (Mg/L)	BOD (Mg/L)	Ratio BOD/COD
Enzymatic	307,221	27,000	13,400	.496
.				
Softwood	438,113	37,000	18,300	.495
Counter-current	668,314	54,000	29,400	.544

Upon evaluation of these initial estimates, a revised general waste treatment flow schematic was developed. This followed the typical evolution of ethanol plant designs over the past 15-20 years. To minimize costs of wastewater treatment and to minimize any makeup water requirements, the ethanol plant designs have incorporated various water recovery/cleanup/reuse schemes. Merrick developed with NREL, a typical scheme which used centrifugation and evaporation to concentrate waste into smaller stream flows.

The revised process(es) developed by others (Delta-T design for evaporation and dehydration, a separate project currently underway) similarly integrate the distillation step with waste treatment processes including evaporation and centrifugation for concentration of solids in the distillation column stillage.

The revised flow schematic includes various streams being recycled (or "backset" in the language of the ethanol industry). The new flow schematic also includes waste treatment streams from ion exchange (detoxification), pretreatment flash vents, syrup and condensate from the evaporator. The new schematic also includes waste waters from boiler and cooling tower blowdown to be included in the overall waste treatment process.

Following these revisions, a preliminary estimate of the strengths of the wastewater was performed. This estimate assumed that the removal of most of the soluble components from the stillage would reduce the COD of the wastewater to 3,000-7,000 mg/L. The assumed parameters for each case are shown below in Table 2.

Table 2

PROCESS	Projected Flow (Kg/Hr.) (MGD)	Projected COD (Mg/L.)
Enzymatic	126,631 (0.8 MGD)	2,938 Mg/L to digester, 235 Mg/L to aerobic
Softwood	173,835 (1.1 MGD)	4,173 Mg/L to digester, 334 Mg/L to aerobic
Countercurrent	250,767 (1.6 MGD)	6,510 Mg/L to digester, 520 Mg/L to aerobic

As can be seen by the stream flows and strengths, the designs will now be suitable for typical industrial "high strength biologically treatable waste water." These waste water streams can be economically treated in either package plants of standard designs or in small custom plants with standard processes. Costs for each system were then projected by vendors and are contained in Appendix F. After the initial cost estimate was completed, the ASPEN model was completed. The ASPEN model used the soluble chemical constituents to project a COD loading into wastewater treatment. The estimate assumed that COD was a measure of the amount of oxygen required to convert all of the carbon in a specific compound to carbon dioxide. For example, the COD of glucose is 1.07 kg oxygen/kg compound and is calculated as follows:

$$C_6H_{12}O_6 + 6\ O_2 = 6\ CO_2 + 6\ H_2O$$

COD of glucose = (6 kgmol O2*32 kg/kgmol)(1 kgmol glucose*180 kg/kgmol)

COD of glucose = 1.07 kg oxygen/kg glucose

The COD values calculated for the components in the NREL process using this methodology are summarized in Table 3.

Table 3
Component COD Factors

Component	COD Factor (kg COD/kg)
C-6 and C-5 Sugars and Oligomers	1.07
Cellobiose	1.07
Ethanol	2.09
Furfural	1.67
Lactic Acid, Acetic Acid	1.07
Glycerol	1.22
Succinic Acid	0.95
Xylitol	1.22
HMF	1.52
Soluble Solids	0.71
Soluble Unknown	1.07
Corn Oil	2.89
Acetate Oligomers	1.07
Acetate	1.07

As shown on the table, the COD for most components is slightly greater than unity. This approximation agrees well with practice; CODs of sugar-based streams generally range from 1 to 1.1 (kg COD/kg component) (Nagle 1998a). This method of approximation, however, did not agree well with the initial estimates of the strength of the wastewater; it resulted in COD loadings that were 5 to 10 times higher than the earlier projections. This discrepancy was due, in part, to the different methods used to determine COD. The initial, lower COD values, were based on a rule-of-thumb estimate where 1 pound of soluble solids was equivalent to 1 pound of COD (Ruocco 1998). This method did not take into account any soluble liquids (e.g., furfural) or the relative flowrates of the soluble solid components. In addition, initial stream flows on PFDs did not include all soluble solids (e.g., ammonium acetate) in its calculation of the soluble solid percentage.

In any case, a reliable method of projecting the COD of the wastewater needed to be developed. Thus, as noted earlier, NREL sent out samples of SSCF effluent from each of the 3 processes to determine the COD content and to test each samples digestibility (Pinnacle 1998; Evergreen Analytical 1998). In addition, a component analysis of the samples was conducted (McMillan 1998). To simulate distillation, all samples were stripped of ethanol using a constant volume technique so that concentration of the species would not occur. Copies of the test results are contained in Appendix G, Attachment 4.

Because these samples were not subjected to evaporation or ion exchange, they do not represent the composition of the streams to the wastewater treatment. However, they can be used to test the methods of COD projection. The predicted COD using the factors in Table 2 and the composition (without ethanol) for the enzyme process (McMillan 1998) is 28,398 mg/l. The average of 3 measured values for the enzyme process (Pinnacle 1998; Evergreen Analytical 1998) is 27,199 mg/l, an error of less than 5%. Thus, the method used in the ASPEN model appears reasonable.

A more detailed compositional analysis of the enzyme sample was also conducted. However, these values were not used due to possible contamination (McMillan 1998a). In addition to the reported values, Attachment 4 of Appendix G contains a spreadsheet that calculates the projected COD value.

Using the methodology outlined for the ASPEN model and using the W9809i model, the strength of the wastewater for the enzyme case is projected to be 32,093 mg/L with a total flowrate 188,129 kg/hr. Since the ASPEN models of the other 2 processes are not yet complete, no new estimate of the strengths and flows of these processes can be made. These parameters were then used to obtain an updated cost estimate for the wastewater treatment process. These costs are contained in Appendix J.

In the initial model, the BOD is calculated as 70% of the COD for all waste streams. This approximation agrees well with published ranges for COD and BOD for similar wastewater (Perry 1998). Although data on SSCF effluent predicts a lower BOD/COD ratio, with an average value of 52% for all technologies (Evergreen Analytical 1998), the wastewater in the model, will have a different composition than that analyzed due to detoxification and evaporation. It is also expected that this ratio will change through each treatment step.

Based on the projected wastewater compositions and the proposed treatment system, the estimated BOD/COD ratio is 0.50 for the influent to anaerobic digestion, 0.20 for the influent to aerobic treatment and 0.10 for the system effluent (Ruocco 1998). Since BOD is a laboratory test and cannot be specifically predicted, the ratios provided above are estimates based on experience with other wastewater systems. The FORTRAN blocks CODCALC1, CODCALC2 and CODEND in the ASPEN model should be updated with the new BOD/COD ratios.

The COD calculations outlined above correspond to the COD loadings for anaerobic digestion. In aerobic treatment, nitrogen-containing compounds such as ammonium acetate will have a significant oxygen demand (e.g., 4.43 kg O_2 required per kg of NH_3).

Since ammonia is not converted in anaerobic digestion, the contribution of the reduced nitrogen compounds is not included in the overall COD calculation. In aerobic treatment, however, these compounds cannot be ignored. This fact requires two significant changes to the model. The first is that reduced nitrogen compounds that are converted in anaerobic digestion (i.e., ammonium acetate and ammonium sulfate) must be treated differently in the ASPEN model. Currently, the carbon and sulfur portions of these compounds are converted to biogas and hydrogen sulfide, respectively, and the other portion is converted to water. This system incorrectly ignores the nitrogen in the effluent from anaerobic digestion. The second major change is in the FORTRAN block CODCALC2. The current COD values are the same as those listed above in Table 3. As discussed, these COD do not include the contribution of reduced nitrogen. This contribution must be accounted for in aerobic treatment.

To remedy this situation, the following specific changes should be made to the ASPEN model:

1. The reduced nitrogen compounds should be carried through the wastewater treatment system as their component ions. Thus, an RSTOIC block should be added prior to the anaerobic system. Here, ammonium acetate would be converted to ammonia and acetate and ammonium sulfate would be converted to ammonia and sulfuric acid.

2. The FORTRAN block CODCALC1 would then need to be modified such that the COD value for acetate was 1.07.

3. Within the anaerobic digestion subroutine, no significant changes would be required except that ammonium sulfate would no longer be converted to hydrogen sulfide and ammonium acetate would no longer be converted to methane, carbon dioxide and water. The new substances, acetate, sulfuric acid and ammonia are already correctly handled in the subroutine. That is, acetate is converted to biogas; sulfuric acid is converted to hydrogen sulfide and water; and ammonia is not changed.

4. As noted earlier, the FORTRAN block CODCALC2 must be modified so that all reduced nitrogen compounds are included in the COD calculation. Since most of these compounds are now noted as ammonia, a new COD factor of 4.43 should be added and applied to ammonia. Ammonium hydroxide should also be added and will have a COD demand of 2.15.

5. The FORTRAN block that calculates the air addition, AERAIR, should be modified so that there is no excess air.

6. The aerobic reactor should be modified so that the ammonia-containing compounds are converted to nitrates as follows:

   $NH_3 + 2.25\ O_2 = NO_3 + 1.5\ H_2O$
   A conversion efficiency of 98% should be used for this reaction.

7. Finally, the FORTRAN block POWER should be modified so that the work stream for the aerators is correct. Each kg of oxygen required uses 2 hp-hr of energy. This should be added to the FORTRAN block as well as an appropriate work stream. The current system comprised of a compressor with an associated work stream should be deleted and replaced as outlined above.

If these changes are made, it is expected that the ASPEN model will correctly simulate the wastewater treatment system. Other strategies would also likely work, but this appears to be the most straightforward method.

V. Waste Water/Sludge Processing

The process flow schematic in the revised recommended configuration retains a burner (sludge incinerator) to combust suspended solids produced by the centrifuge and to probably combust the syrup produced by the evaporator.

The inclusion of a waste burner system is to be compared with alternate sludge processing options in this report. These other options include land application of the sludge, with or without first composting the sludge. Also, this analysis includes the evaluation of the alternatives of evaporation and final treatment by a Publicly Owned Treatment Work (POTW). As can be seen in Appendix B, the relative costs of evaporation and POTW treatment appear to be typically more expensive than onsite treatment of the Ethanol Facility effluent.

VI. Evaporation

<u>Combustion of Fuel for Evaporation or Incineration</u>

The typical methods of evaporation of waste water effluent include energy sources of solar, fuel or waste heat. The alternative of incineration is similar to direct evaporation, especially with respect to the fuel requirements. For an average 1 MGD load of Waste Water (Option I for the Enzymatic Process; higher flows are expected for the other two processes), the energy requirement is about 1 x 8.33 pounds/gallon x 1,000,000 gallons x 1100 Btu per pound (to evaporate at low temperature only) per day. If the energy source is fuel at about $2.20 per million Btu, the cost would be about $20,000 per day or over $7 million per year. Over a 20-30 year life of the project, the fuel cost alone could total over $100 million, or more if fuel costs rise. The capital cost for the evaporation or incineration equipment and the operating and maintenance cost will be additional to this. ***Since the anticipated cost for other alternatives such as treatment by a POTW or on-site treatment is expected to be one-half this cost or less, we will not consider this alternative further.***

Solar Evaporation

If the site has adequate space and adequate solar energy, the costs may be less. Typically solar evaporation is used where there is a net evaporation from a shallow pond after new rainfall adds to the evaporation load. The typical range of net evaporation is 1 to 10 inches of exposed surface per month (1 inch in winter, 10 inches in summer). This translates to 27,154 gallons per acre per month at the minimum. Actual land space required to pond the waste water safely will be about 120-130% of the evaporation surface to allow for dikes, access, etc. In addition, the design should include a holdup volume for storage of excess (peak) waste water and for extended winter evaporation rates.

With a typical net winter evaporation rate of 27,154 gallons per acre per month, even the well integrated Enzymatic Biomass-to-Ethanol facility (about 1 MGD waste water average; about 1.5 MGD design for peak flows) would require well over 1000 acres of land dedicated to solar evaporation. This would include a combination of peak storage for winter and adequate surface area for summer evaporation of average flow plus part of the stored volume. At a cost of about $1200 per acre plus an additional $800 per acre for diking, pumping and piping, etc., this would cost over $2,000,000 for the land alone, if such a large area could be located near the facility. Operating and Maintenance costs, including removal of accumulated solids, would be additional to this. The other Biomass-to-Ethanol processes would require larger acreage and a resulting higher capital and operating cost. ***It is not expected that sufficient land space will typically be available due to the expectation that the location of a biomass facility will not be in an arid, hot, flat region. If a biomass facility is located in such a region, this alternative should be reevaluated using local design information.***

Waste Heat Evaporation

If the Biomass-to-Ethanol facility has any waste heat available, it should already be recovered for other duties in the process if it is economical. This is evident by the sophisticated integration around the evaporator and distillation systems for the developed ethanol plant designs. If excess waste heat is available, it is expected to be at a low level, requiring a vacuum evaporation system with its associated capital and operating costs. The size/cost of this equipment is highly dependent on the available heat level. There may be some significant heat available in the boiler exhaust portion of the facility. However, this heat is most properly integrated into a lignin or other biomass fuel or product drying operation to minimize the fuel required to fire the boiler and to provide boiler feed water preheating.

VII. Irrigation

Another land application alternative is to apply a waste water stream directly to the land in an irrigation situation. This is different than solar evaporation and the application rate to the ground is typically higher since the water is used for a crop. Typical crops could eventually be part of the biomass feed stock for the ethanol facility. However, at present for an existing site, sufficient land and the associated growing season and crop farming operators may not exist.

Handbook of Applied Hydrology by Ven Te Chow, and Wastewater Engineering Treatment, Disposal, and Reuse by Metcalff and Eddy, (the McGraw Hill series in water resources and environmental engineering) were used to ascertain some data contained herein.

Some important aspects of land application for irrigation are:

- Large storage capacity is typically required to accommodate the times when application will not be allowed. This includes about 3-4 months of storage for the winter months, especially if the ground freezes. Land application is not allowed if the land surface is frozen. Also, there may be additional storage required, or additional land required, to accommodate the harvesting of the crop. Overall, full application rates to the soil may be limited to less than one-half the year.
- Concentrations of various contaminants may severely restrict the potential crop choices. Actual experience with a Front Range brewery waste water applied to alfalfa caused cattle feed problems. As a result, the waste water is now applied only to turf farms. This does not appear to be a reasonable design choice for continuous discharge of the waste water.
- Large land areas must be dedicated to the application of waste water. Certainly, in hot and arid regions, waste water is applied to golf courses or park land. However, these areas are typically not adjacent to forest products plants.

VIII. Other Wastewater and Sludge Treatment Alternatives

Another sludge disposal option could be the development of commercial markets for these materials. Such markets could be envisioned as a market for their chemical constituents, a market for these materials as animal feeds or as soil enhancement additives. This co-product development is beyond the scope of this report, however is highly recommended by the contractor for further development to enhance project economic viability.

IX. Suggested Treatment Options:

As can be seen from Table 2, the reduced flows from the three processes average between 1.0 and 2.2 MGD of total flow to the waste treatment block on the process flow schematic. Actual design flows will be higher than these daily averages to account for variations in operation and unexpected equipment unavailability. The attached Appendix E shows typical actual design sizing to accommodate peak daily, weekly, etc. flows.

The suggested treatment system should be a combination of anaerobic biological treatment followed by aerobic biological treatment. This recommendation is based on the calculated flow rates as well as the suggested waste strength.

Anaerobic and aerobic facilities in the 1 to 5 MGD range can be obtained in a variety of process and facility types ranging from custom engineered and constructed "municipal" facilities to vendor distributed and installed package type plants.

For the first draft of this report, contact was made with vendors of "off-the-shelf" package type anaerobic and aerobic plants.

Anaerobic units were selected by Phoenix Biosystems of Colwich, KS, and aerobic units of the sequential cell, aerated, fabric lined earthen pond type were provided by Globe Sampson Associates, Englewood, CO.

These two vendors each provided a table listing the basic equipment and installed cost for their respective units. The tables in Appendix F summarized the two vendor submittals for this draft report.

X. Discussion of Expected Effluent Quality

In general, with influents over 1000 Mg/L BOD, anaerobic digestion (treatment) is the preferred first treatment step. Anaerobic treatment of soluble organics will average over 90% reduction on a COD basis.

For effluents from the anaerobic treatment as influent to the aerobic treatment step of up to 400 Mg/L BOD, the effluent from the aerobic treatment system will average below 10 Mg/L BOD and TSS (Total Suspended Solids).

For effluents from the anaerobic treatment as influent to the aerobic treatment step of between 400 Mg/L to 800 Mg/L BOD, the effluent from the aerobic treatment system will average below 20 Mg/L BOD and TSS.

For effluents from the anaerobic treatment as influent to the aerobic treatment step of up to 1000 Mg/L BOD, the effluent from the aerobic treatment system will average below 30 Mg/L BOD and TSS.

As the site of the proposed facility and therefore the ultimate discharge of the effluents from the waste water treatment facility are unknown, 30 Mg/L BOD and TSS are suggested targets for maximum discharge parameters. 30 Mg/L BOD and TSS are usual stream discharge requirements for the average Western US stream. For the analysis in this report, the discharge standard of 30 Mg/L BOD and TSS are used as the required treatment standard for effluent from the Biomass-to-Ethanol facility. The fact that a particular project effluent could be higher quality than the regulation of 30 Mg/L BOD and TSS does not typically change the requirement for both an anaerobic and an aerobic treatment step. However, if the typical "treatment step" appears over-designed, the design should be evaluated for potential cost savings by reducing the size (residence time) of the equipment to match system performance to the effluent requirement.

Other parameters for waste water discharge requirements such as toxins, metals, nitrogen and phosphorous will have a bearing on treatment steps in the waste treatment scheme finally selected. ***confirm that the list of contaminants does not contain high concentration constituents -- and note this here*** The selected site specific discharge point will have a large effect on the difficulty of treatment and the discharge requirements for these parameters. Since the expected effluent from an unspecified location with a Biomass-to-Ethanol facility does not contain unusually high levels of normally suspect contaminants, this analysis will not have any adjustments for isolated contaminants. However, if a project has a new feed stock with significant levels of regulated contaminants, the project economics should include additional capital and operating costs to properly treat these contaminants.

XI. ASPEN Model

A waste water treatment model was developed and incorporated into an NREL base model (W9806F). The resulting model, P9808B, has been checked into the Basis database. Appendix G gives a detailed description of the model development plus a listing of changes and subroutines.

XII. Treatment of Anaerobic Digester Off Gas

Anaerobic digester off gas is primarily a mixture of methane and carbon dioxide. It is burned in the boiler to recover the heat of combustion of the methane. Late in Task 3 it was noticed that the waste water contains sulfates which will convert to hydrogen sulfide in the digester. The resultant hydrogen sulfide concentration in the off gas is approximately 1800 ppm (wt.). At this concentration the gas must be considered toxic. Further the boiler stack will emit approximately 1.14 tons/day of sulfur to the atmosphere (tons/day of SO2). It is believed that this emission rate would not be permitted in the U.S. EPA regulations are site specific but a useable rule of thumb is less than 100 tpy of SO2 emissions is allowable. Also the anaerobic off-gas will meet toxicity definitions in OSHA 29 CFR 1910.119 and EPA 40 CFR.

It should be noted that the fluidized boiler which burns the anaerobic off-gas may include limestone addition for other sulfurous components in the lignin fuel. If this is the case treatment in the combustion chamber may be more economical than the options described below. The boiler is not in Merrick's work scope.

Two potential treating options were briefly considered to remove hydrogen sulfide from the off gas:

1. <u>Iron Sponge Process and SulfaTreat Process</u>

   SulfaTreat is a proprietary process licensed by the SulfaTreat Company, Chesterfield, MO. The process is a vast improvement over the generic iron sponge process. However, because of the large flow rate and daily sulfur tonnage, the SulfaTreat Company found that their process is not practical for the 2000 bone dry tons per day plant size. This is because the process reacts hydrogen sulfide with beads impregnated with ferric oxide. As the ferric oxide is consumed the beads must be changed out. The beads cannot be regenerated but are suitable for landfill. At the large plant size 6500 cubic feet per month of beads are consumed which is impractical. Plant sizes under 1000 bdt/d should consider the SulfaTreat process.

2. <u>Direct Oxidation Processes</u>

   U.S. Filter was contacted concerning their Lo-Cat process for the direct oxidation of hydrogen sulfide to elemental sulfur. Lo-Cat is a well known process in the natural gas processing industry and also has extensive application to anaerobic off gas. Several companies offer similar direct oxidation processes.

   Lo-Cat can produce the elemental sulfur in several physical forms depending on the market for this material. Most elemental sulfur produced in the U.S. is consumed by the fertilizer industry. The price obtainable for this byproduct is highly site specific and has not, as yet, been included in the plant economics.

   U.S. filter estimates the bare equipment cost the Lo-Cat equipment will be $1,500,000 which is a considerable increase over the previous allocation of approximately $56,000 for off gas handling (M-606).

XIII. Plant On-stream Factor

The capital to be invested in equipment sparing must be carefully evaluated against the predicted increase in on-stream factor for the entire plant including the waste treatment sections. The flowsheets and model currently indicate a number of the pumps to be spared yet certain services such as P-611, Clarifier Feed Pump, do not have a spare. Merrick feels it may be possible to delete all installed spares downstream of the aerobic lagoon as the lagoon can be made marginally larger and provide the necessary surge time for equipment repairs. In each case the investment in warehouse spares must be considered based on availability and delivery time for parts. This must be evaluated against the potential for boiler upset due to sudden load variations and against the cost of the larger lagoon. The filter press is in this part of the process and is considered a high maintenance service.

The large decanting centrifuges, S-601 A/D, are key equipment items and each machine is very expensive ($750,000 each, not installed). However this is a difficult service and will have significant individual machine off-stream maintenance. High Plains Corp. at York, NE (corn to ethanol) has multiple spares in a very similar service and list these decanters as one of the three highest maintenance services in the plant.

Rotating machinery of nearly all types tends to have relatively high maintenance. The York plant also listed long-shaft tank agitators in their fermentors and all of the solids/cake conveyors.

Many of the pumps in the plant are moving slurries and these pumps have a much higher maintenance history than pumps moving only liquids provided that the temperatures and pressures are in a normally encountered operating range.

An evaluation of predicted failure frequency, duration of repairs and cost of lost production versus the cost of installed or warehouse spares is the classic method of determining if a spare equipment should be purchased, provided the necessary performance data is available. This evaluation is beyond the scope of the current work.

XIV. General Plant Considerations

The High Plains Corp. of York, NE uses variable speed electric drives in many of their rotating equipment services. They have found this a superior method of process control. Alternatives have maintenance and efficiency drawbacks:

1. Throttling control valves in mixed phase (solid/liquid) service are subject to erosion and plugging. They are considered high maintenance items.
2. Pump arounds can be made practical when properly sized but waste energy in the discharge to suction loop.

3. Belt and screw conveyors can also use recycle (spill-over) control methods but suffer from the same inefficiencies.

It is advisable to consider variable speed drivers for NREL designs. The cost of variable speed electric drives is higher than fixed speed but this may be justified by avoiding expensive specialty control valves, avoiding recycle loops, increasing operating ease, enhancing start-up reliability etc. In this regard, depiction of control methods would enhance the flow sheets and allow more meaningful pressure profiles, hydraulics and pump sizing.

XV. Environmental Emissions

The biomass to ethanol facility is a specific group of chemical processes which in general, break down cellulose and lignin complexes in to sugars. The sugars are subsequently fermented by yeast or bacterial action into ethanol and other left over compounds and biomass.

The basic steps include pretreatment processes which break down the cellulose and lignin complex to simpler compounds and finally with suitable chemicals or enzymes into sugars. These sugars are fermented by either yeast or bacteria yielding ethanol, biomass and left over molecules. The weak beer is consequently distilled and otherwise treated to yield high proof ethanol which is the main product of this process and leftover compounds in the form of suspended and dissolved solids in liquid streams. The leftover compounds become either byproducts worth money, or must be treated as liquid or solid wastes. The biological based feedstocks make the production of most hazardous compounds not an issue. However, some compounds classified as toxic will have to be treated in the waste treatment processes associated with the biomass to ethanol facility.

The biomass compounds which make up the feedstocks for these facilities may be as simple as sugar or ethanol solutions, or as complex as hardwoods, and the leftover molecules from the processing steps will be varied as well.

<u>The fate of left over molecules:</u>

Emissions from sewage treatment plants are in the form of odors and VOC's emitted from the various treatment processes. Molecules not emitted can be "bioconverted" into other molecules and compounds which may be emitted or form part of the biomass or sludge left over from the treatment process. Finally molecules not emitted or bioconverted can be reported as liquid borne emission in the effluent liquids or as semi solid sludge from the waste treatment process. The **<u>FATE</u>** of the produced molecules and compounds in the waste treatment process is the subject of this section of the report.

To discover the FATE of the many potential compounds and molecules that a biomass to ethanol facility can generically produce is beyond the scope of this general section. The authors of this report have had success using one of the many computer models which can trace the fates of molecules in a sewage treatment facility.

Computer models such as “BASTE” (Bay Area Sewage Toxic Emissions), “CHEMDAT 7”, and “SIMS” are examples of commercially available computer models which can be tailored to the exact series of processes that comprise the sewage treatment plant in question. The models each contain embedded data bases containing many chemical compounds which have been found in sewage influents at actual sewage systems. The data bases have bioconversion constants for the biotreatability and Henry’s Constants for the emission and or solubility or each compound.

The model consists of a series of mass transfer algorithms coupled with bioconversion formula which taken in a series consistent with the sewage treatment plant being modeled, allow the concentration of the sewage stream to be calculated for each process in the sewage treatment train. Thus the environmental emissions of any sewage treatment process can be approximated.

Releases to the air, land ,water and other:

Project designers typically use check lists specifically tailored for the biomass to ethanol plant designer. The check lists for air, land, water, and other emissions, will allow the designer to be aware of specific emissions from the plant in each release category. This will allow the designer to begin a permitting process in an early stage in the plant design. Construction permits from Environmental agencies typically require as much as a year of effort to obtain, depending on the specific site of the proposed facility.

Air releases:

An example of such a check list is as follows:

Release	Relevant to the Site	Relevant to the facility	Permitted amount.
Sulfur dioxide	X	X	100 TPY
NOX	X	X	
CO	X	X	
PM10	X	X	25 TPY
Lead			
VOC	X	X	
CO2			
CH4			
Acetaldehyde			
Formaldehyde			
Other toxics			
Radionuclides			
Thermal emissions			

The expected concentration of each compound identified in the waste stream would be entered into the properly configured BASTE or SIMS model of the sewage system for the ethanol facility. The actual calculation of emissions for that compound both in the air and in the effluent would be the output of the model. In this way, the checklist can be filled and the permit process initiated.

Water releases (releases with effluent):

Release	Relevant to the Site	Relevant to the facility	Permitted amount
BOD			
TSS			
NH4			
NO3			
Oil and grease			
Priority pollutants			
Thermal emissions			

As with air, the amounts of compounds can be entered into the table and the calculated resultant emissions can be included as part of the permit process and the eventual permit for the ethanol facility.

Land concerns:

Land area to dispose of the solid and semisolid residue of the plant will be a concern to the plant designer. Typically, nutrients contained in the sludges will determine how many pounds of the material can be applied to an acre of land during a crop season. In colder climates, sludges cannot be applied to frozen ground and require storage for 180 days, provision for such storage will have to be part of the initial plant design.

<u>Other concerns:</u>

Other concerns of the plant designer will be Health and Safety, Noise, Odors, Catastrophic Events and Aesthetics. Each item should be addressed by the facility designers to match the local requirements.

<u>Emission measurements at operational ethanol facilities:</u>

Emission measurements may be required by the regulatory authorities. Such measurements may be in the form of “stack tests” at the boiler and other vent stacks. Such tests usually monitor for PM10, VOC’s and toxics. Measurement of the emissions from the waste treatment facility can be avoided by careful configuration and operation of the BASTE or SIMS models which provide an answer for the regulatory agencies which has been accepted by the agencies when applied. Typically operation of the computer model is much less expensive than is the field testing required to actually measure actual emissions. The result of the model is frequently a better look at actual emissions than is the "snap-shot" look that results from field testing.

<u>Emission treatment at operational ethanol facilities:</u>

Sewage plant VOC emissions can be easily controlled by covers over the emitting unit operations. Weir covers and covers over manholes and other sewage structures where waste streams come in contact with the air are the treatment choices due to the low cost of such control measures. Typically unit operations where odors are emitted in sewage plants are also the areas where VOC’s are emitted. Odor control usually provides some measure of VOC control.

The sludge incinerators, spent grain driers, and/or the steam boilers employed at ethanol facility, are all subject to PM10 and VOC emission controls. Waste gas flares for biogas from anaerobic processes must also be designed for low emissions. For very large power plant boilers, NOX control such as low NOX burners must be employed.

XVI. Environmental Regulations and Permits

Similar to the Report Section XV on Emissions from Ethanol Plants, this report Section will address the Regulations and Permits required to construct and operate a typical facility in the USA.

This section addresses the regulations and permits required to release discharges into the air, into a water body/stream, and onto land. Each of these areas has had regulations issued at the Federal, State and Local levels. Permits associated with these regulations are often managed at the State or a Local level as directed by the Federal and State Statutes. Sometimes the authorizing agency may be the State itself, a Regional District or Agency, a County, and/or a City or other smaller entity. Whichever discharges are contemplated, the first step is to determine the agency(ies) having jurisdiction for the actual plant location and for each discharge contemplated.

Most local or state governments maintain an "Assistance Center" to guide the new Facility Owner through the applicable regulations and how to obtain the required permits for construction and operation. The particular "center" may be called a "Permit Assistance Center" or "Technical Assistance Center" or a similar title. Local county agencies will be able to determine the best method of establishing the jurisdictional agencies for the emissions from the new Ethanol Facility.

For construction and operation of a new Ethanol Facility that will be co-located at an existing host site, the discharges may become part of the existing host discharges with modifications to existing permits. Therefore, in addition to determining the agencies having jurisdiction, the new Ethanol Facility Project Owners must also determine if the Facility will be operated as a separate entity or as an addition (modification) to an existing facility. This report will not address specifically the permit requirements of a co-located, co-owned Facility, since the permit requirements will be determined by the (modification of the) existing permits for the host site. However, the comments about the emissions (previous Section XV - Environmental Emissions and Effects) and the related permits for an Ethanol Facility (below) will be applicable to the modifications of the existing permits.

Other Regulations

The Wastewater Treatment Systems at a new Ethanol Facility will be subject to many regulations other than the air, water and solid waste regulations. Typical of these will be the Occupational Health and Safety Act (OSHA) regulations about personnel safety. These regulations will address standard safety aspects of such things as ladders, personnel access, confined spaces, etc. Another series of regulations will be the National Fire Protection Association and the American Petroleum Institute standards regarding the methane and hydrogen sulfide gases evolving from the anaerobic treatment of wastewater. Also, the electrical devices used in the wastewater treatment systems may require Underwriters Laboratories (UL) certification for certain components. This report will not address these specifically since these regulations and standards will apply to the whole Ethanol Facility.

Air, Water and Solid Waste Regulations and Permitted Quantities of Emissions

For each type of environmental emission, the Owner must determine the type and quantity of each specific regulated constituent that may be contained in the intended discharge. For example, the air emissions may contain particulates (PM10), Volatile Organic Compounds (VOC's), and other similarly regulated constituents.

The Owner must estimate to a sufficient degree the maximum, the average, and/or the total expected emission of each category of release to the atmosphere, the water, and the land. Sufficient controls (engineered equipment and operating procedures) and monitoring/reporting must be put into place at the Facility to ensure that the Owner will be able to comply with the limits of his proposed emission types and quantities.

Location of Ethanol Facility

The regulations require permits for construction and operation of an Ethanol Facility that depend on the facility location. Basically, this may range from an undisturbed "greenfield" site to a previously occupied or existing industrial site. Also, and this may be equally important, the facility site may have no nearby neighbors or may be surrounded with residential or other neighbors. The presence of a local population may impact allowable limits for such emissions as odors (even during emergency situations), visual aesthetics, etc. Thus, even though odor is not currently regulated under any federal program, state and local regulations may require that odor control be specifically addressed (to the satisfaction of the local populace).

As a location for the Ethanol Facility is determined, the local authorities should be contacted to establish the various requirements for the Permitting of the Facility. Planning Departments of the City/County or similar entity sometimes offer an organized approach to permitting with a "Permit Assistance Center" or similar organization. These organizations should be contacted to determine which agencies participate at that one location. These organizations also provide checklists of required permits and compliance information, including ongoing operational monitoring and reporting requirements. These checklists should be utilized to set up the Operation and Maintenance procedures for the Ethanol Facility. An example is available on the Internet at *http://smallbiz-enviroweb.org/htm/regchecklist.asp*.

Air Emission Regulations and Permits

Federal Clean Air Act and Amendments

The Federal Clear Air Act, originally promulgated in 1963, has been modified and upgraded in content and requirements by various Amendments in 1967, 1970, 1977 and 1990. The Act and its Amendments require State Implementation Plans or the Federal Environmental Protection Agency (EPA) will provide the implementation. States that have implemented the requirements of the Clean Air Act may also allow the participation of local governments in controlling air pollution within their territorial jurisdictions.

While the wastewater treatment section of the Ethanol Facility typically controls the wastewater in piping and tanks, etc., any storm water that is received by the Facility must also be contained and addressed as required. Storm water on the Facility site may fall into various categories requiring different treatments. For example, storm water on roads and parking lots may only require a surge volume control before slow, controlled release to the natural receiving water. However, storm water in the main process units may require hydrocarbon separation treatment steps to remove any spillage existing on the contained process area. Also, storm water on an uncovered wood chip storage pile will produce a leachate that contains material which will settle and that must be removed before discharge of the storm water. The design of the Facility should incorporate a coordinated approach of equipment and procedures for containment and treatment of all storm water received by the Facility.

<u>Water Emission Regulations and Permits</u>

The information below has been adapted from the reference item "Wastewater Engineering Treatment, Disposal and Reuse" and gives typical guidelines for the discharge of wastewater to a receiving body.

A National Discharge Elimination System (NPDES) program was established based on uniform technological minimums with which each point source discharger had to comply.

Pursuant to Section 304(d) of Public Law 92-500, the U.S. Environmental Protection Agency published its definition of secondary treatment. This definition, originally issued in 1973, was amended in 1985 to allow for additional flexibility in applying the percent removal requirements of pollutants to treatment facilities serving separate systems. The current definition of secondary treatment is reported in the table below. The definition of secondary treatment includes three major effluent parameters: 5-day BOD, suspended solids, and pH. The substitution of 5-day carbonaceous BOD ($CBOD_5$) for BOD_5 may be made at the option of the NPDES permitting authority. Special interpretations of the definition of secondary treatment are permitted for publicly owned treatment works (1) served by combined sewer systems, (2) using waste stabilization ponds and trickling filters, (3) receiving industrial flows, or (4) receiving less concentrated influent wastewater from separate sewers.

Minimum national standards for secondary treatment[b]

Characteristics of	Unit of	Average 30-day	Average 7-day

discharge	measurement	concentration	concentration
BOD_5	mg/L	30[c,d]	45[c]
Suspended solids	mg/L	30[c,d]	45[c]
Hydrogen-ion concentration	pH units	Within the range of 6.0 to	9.0 at all times[e]
$CBOD_5$ [f]	mg/L	25[c,d]	40[c]

[b] Present standards allow stabilization ponds and trickling filters to have higher 30-day average concentrations (45 mg/L) and 7-day average concentrations (65 mg/L) BOD/suspended solids performance levels as long as the water quality is not adversely affected. Exceptions are also permitted for combined sewers, certain industrial categories, and less-concentrated waste water's from separate sewers.
[c] Not to be exceeded.
[d] Average removal shall not be less than 85 percent.
[e] Only enforced if caused by industrial wastewater or by in-plant inorganic chemical addition.
[f] May be substituted for BOD_5 at the option of the NPDES permitting authority.

In 1987, Congress completed a major revision of the Clean Water Act. Important provisions of the WQA are (1) the strengthening of federal water quality regulations by providing changes in permitting and adding substantial penalties for permit violations, (2) significantly amending the CWA's formal sludge control program by emphasizing the identification and regulation of toxic pollutants in sludge,

In response to the provisions of the Water Quality Act, new regulations have been promulgated or proposed for controlling the disposal of sludge from wastewater treatment plants.

In 1989, the EPA proposed new standards for the disposal of sludge from wastewater treatment plants. The proposed regulations established pollutant numerical limits and management practices for (1) application of sludge to agricultural and non-agricultural land, (2) distribution and marketing, (3) monofilling or surface disposal, and (4) incineration.

Trends in Regulations

Regulations are always subject to change as more information becomes available regarding the characteristics of wastewater, effectiveness of treatment processes, and environmental effects. It is anticipated that the focus of future regulations will be on the implementation of the Water Quality Act of 1987. Receiving the most attention will be the pollutional effects of storm water and nonpoint sources, toxics in wastewater (priority pollutants), and as noted above the overall management of sludge, including the control of toxic substances. Nutrient removal, the control of pathogenic organisims, and the removal of organic and inorganic substances such as VOCs and total dissolved solids will also continue to receive attention in specific applications.

Other Regulatory Considerations

In addition to the requirements established under the 1987 Water Quality Act and enforced by the U.S. Environmental Protection Agency, other federal, state, and local agencies prescribed by the Occupational Safety and Health Act (OSHA) which deals with safety provisions to be included in the facilities' design. State, regional, and local regulations may include water quality standards for the protection of the public healthy and the beneficial uses of the receiving waters, air quality standards for the regulation of air emissions (including odor) from treatment facilities, and regulations for the disposal and reuse of sludge. Because all of these guidelines and regulations affect the design of wastewater treatment and disposal facilities, the practicing engineer must be thoroughly familiar with them and their interpretation and be aware of contemplated changes. Contemplated changes and current interpretations of the regulatory aspects of water pollution control are summarized in various weekly publications.

XVII. Summary and Conclusions

Several important results were disclosed during this work, among those were:

1. The waste water streams for the three NREL processes (co-current enzyme, softwood, hardwood) are all within the same typical treatment methodology: Anaerobic Treatment followed by Aerobic Treatment.

2. Waste water minimization through judicious water recycling is economically advantageous compared to once-through water use.

3. Although treatment must be judged anew for each specific plant site, the anaerobic followed by aerobic treating processes appear to be, most often, advantageous.

4. The anaerobic digester off gas is potentially laden with hydrogen sulfide in sufficient quantities to require sulfur removal processing.

5. The capital cost estimate resulted in a total installed cost for the 2000 bdt/y feed rate case of $11,362,700. Please refer to Appendix F for the structure and backup of this estimate.

Further Work

Several areas indicate the need for more development :

1. Treatment of the anaerobic off gas stream for the enzymatic process. This stream may contain sulfur (as hydrogen sulfide) in concentration to be toxic and to require clean-up prior to combustion.
2. The methane to carbon dioxide ratio in the anaerobic digester off gas is variable with the operation and the proprietary license. This ratio needs to be established for the plant economic assessment.
3. A 1986 EPA regulation includes a classification of "ethanol for fuel". This regulation needs to be analyzed for potential benefits.
4. The waste water section should be considered for a environmental model to assist in design and to replace on-site sampling when plants are built.
5. Some waste streams were not considered which may have significant impact. Namely : periodic vessel drains for maintenance, storm water falling within curbed areas, chip stock pile leachate, etc. Additionally the effects of listed chemical inventories are not fully developed. These chemicals include natural gasoline denaturant, BFW chemicals, WWT chemicals, lube oils, various acids and bases.
6. VOC emissions for the above chemicals should be evaluated.

XVIII. References

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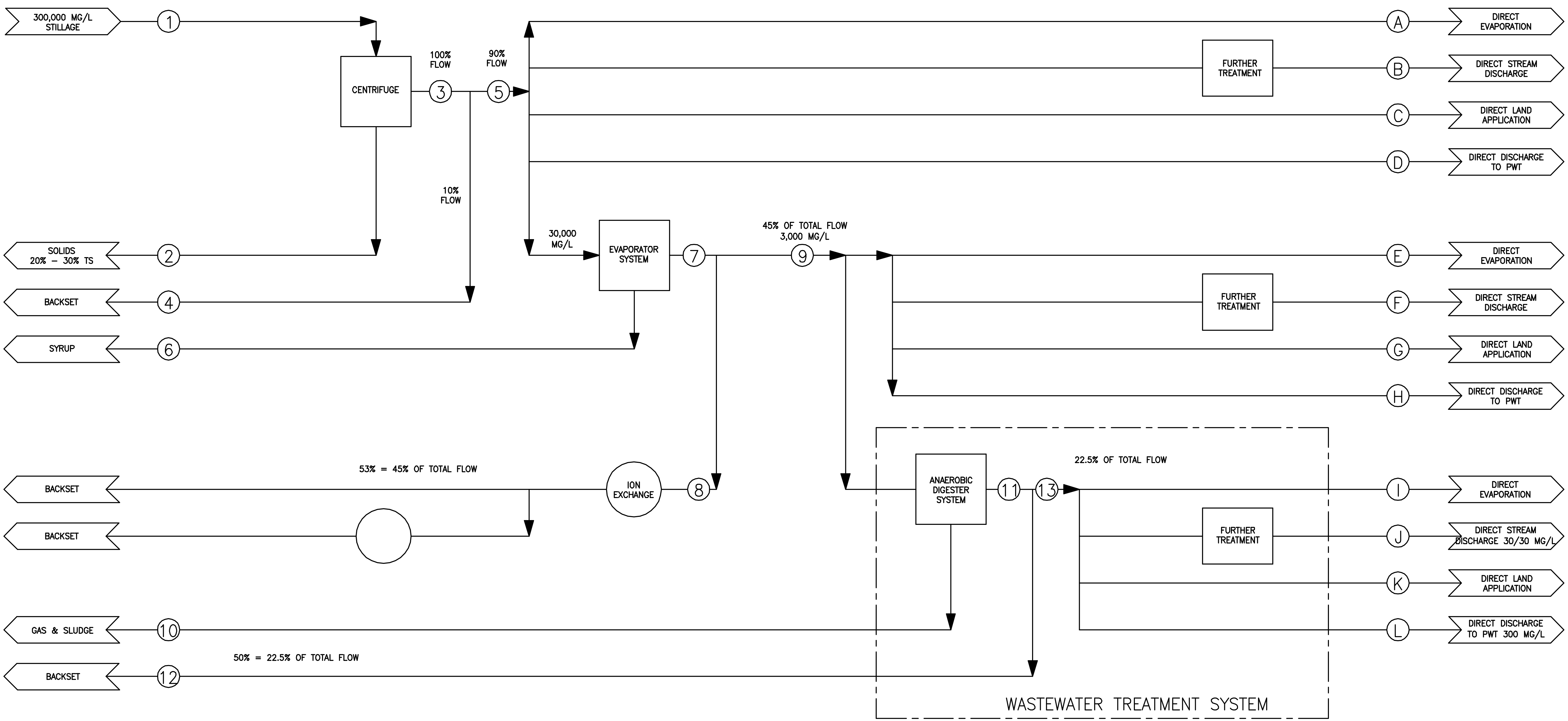
Appendix A

Process Map

"MAP" OF TREATMENT OPTIONS



VER	DESCRIPTION	DATE
A		6/19/98

NREL NATIONAL RENEWABLE ENERGY LABORATORY
Biotechnology Center For Fuels And Chemicals

WASTEWATER TREATMENT PROCESS OPTIONS

1–1 | A

MAP

DISCUSSION OF POSSIBLE OUTCOMES OF TREATMENT AND DISPOSAL OPTIONS:

OUTCOME	DISCUSSION
A. (Stream 5 from Centrifuge) **Direct Evaporation**	Extremely energy intensive, not recommended.
B. (Stream 5 from Centrifuge) **Direct Stream Discharge**	Not permissible in the USA without extensive treatment.
C. (Stream 5 from Centrifuge) **Direct Land Application**	Very large land acreage required.
D. (Stream 5 from Centrifuge) **Direct Discharge to PWTP**	Extremely expensive as flow and load are each very high.
E. (Stream 9 from Evaporator) **Direct Evaporation**	45% of A. with the same result.
F. (Stream 9 from Evaporator) **Direct Stream Discharge**	Not permissible in the USA without further treatment.
G. (Stream 9 from Evaporator) **Direct Land Application**	45% of E with the same result.
H. (Stream 9 from Evaporator) **Direct Discharge to PWTP**	Still very expensive.
I. (Stream 13 from Anaerobic System) **Direct Evaporation**	A possible outcome.
J. (Stream 13 from Anaerobic System) **Direct Stream Discharge** **30/30 mg/L**	A possible outcome, but not permissible without some further treatment.
K. (Stream 13 from Anaerobic System) **Direct Land Application**	A possible outcome, but very site specific.
L. (Stream 13 from Anaerobic System) **Direct Discharge to PWTP** **300 mg/L**	This is a possible outcome.

Add expected costs for each at 1 MGD or other flow to show that the expected typical case will be on-site treatment.

version 3-30-98	Map mass balance												
flow no.	1	2	3	4	5	6	7	8	9	10	11	12	13
flow name	stillage	centrifuge solids	centrifuge liquids	centrifuge backset	feed to next process	evaporator syrup	evaporator condensate	evaporator backset	feed to methanator	methanator effluent	Methanator backset	feed to aerobic treatment	aerobic effluent
flow rate kg/h	438,183.0	2,081.4	436,101.63	43,610.16	392,491.47	43,724.87	348,766.60	174,383.30	174,383.30	174,383.30	87,191.65	87,191.65	87,191.65
backset (%)	0.0	0.0	0.00	10.00	0.00	0.00	0.00	50.00	0.00	0.00	50.00	0.00	0.00
% TS	3.8	21.0	3.71	3.71	3.71	30.00	0.42	0.42	0.42	0.0363	0.04	0.04	0.002
% Suspended Solids	0.1	18.0	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.0029	0.0029	0.0029	0.0002
%dissolved solids	3.7	63.1	3.71	3.71	3.71	29.96	0.42	0.42	0.42	0.03	0.033	0.033	0.00
% moisture	96.2	79.0	96.29	96.29	96.29	70.00	99.58	99.58	99.58	99.96	99.96	99.96	99.99
kg/h of moisture	421,553.0	1,643.6	419,929.14	41,992.91	377,936.23	30,607.41	347,311.08	173,655.54	173,655.54	174,320.06	87,160.03	87,160.03	87,182.93
kg/h suspended solids	394.4	374.6	19.72	1.97	17.75	17.75	0.00	0.00	0.00	5.02	2.51	2.51	0.15
kg/h of total solids	16,630.0	437.8	16,192.20	1,619.22	14,572.98	13,117.46	1,455.52	727.76	727.76	63.24	31.62	31.62	1.46
kg/h of dissolved solids	16,235.6	63.1	16,172.49	1,617.25	14,555.24	13,099.71	1,455.52	727.76	727.76	58.22	29.11	29.11	1.31
kg/h COD	16,630.0	437.8	16,192.2	1,619.2	14,573.0	32,793.7	1,455.5	727.8	727.8	58.22	29.11	29.11	1.46
mg/l COD	37,952.2	210,340.0	37,129.4	37,129.4	37,129.4	750,000.0	4,173.3	4,173.3	4,173.3	333.9	333.9	333.9	16.7
Bioreactor Loading (kg/m3/d)									12.00			1.00	
Bioreactor Volume (m3)									1,455.52			698.65	
COD Reduction									0.92			0.95	
Biogas Production (m3/d)									3,936.90			0.00	

version 3-30-98	Map mass balance												
flow no.	1	2	3	4	5	6	7	8	9	10	11	12	13
flow name	stillage	centrifuge solids	centrifuge liquids	centrifuge backset	feed to next process	evaporator syrup	evaporator condensate	evaporator backset	feed to methanator	methanator effluent	Methanator backset	feed to aerobic treatment	aerobic effluent
flow rate kg/h	668,314.0	38.8	668,275.20	66,827.52	601,447.68	98,264.72	503,182.97	251,591.48	251,591.48	251,591 48	125,795 74	125,795 74	125,795 74
backset (%)	0.0	0.0	0.00	10 00	0.00	0.00	0 00	50.00	0 00	0.00	50 00	0 00	0 00
% TS	5.4	22.4	5.45	5.45	5.45	30.00	0.65	0.65	0.65	0.0566	0.06	0 06	0 003
% Suspended Solids	0.0	18.0	0.00	0.00	0.00	0.00	0.00	0.00	0 00	0.0045	0 0045	0 0045	0 0003
%dissolved solids	5.4	1.7	5.45	5.45	5 45	30.00	0.65	0 65	0.65	0 05	0 052	0 052	0 00
% moisture	94.6	77.6	94.55	94.55	94.55	70.00	99.35	99.35	99 35	99 94	99 94	99 94	99 99
kg/h of moisture	631,911.0	30.1	631,881.27	63,188.13	568,693.14	68,785.30	499,907.51	249,953 76	249,953 76	251,449.16	125,724 58	125,724 58	125,783 16
kg/h suspended solids	7.4	7.0	0.37	0.04	0.33	0.33	0.00	0.00	0.00	11.30	5 65	5 65	0 33
kg/h of total solids	36,403.0	8.7	36,394.30	3,639.43	32,754.87	29,479.41	3,275.45	1,637.73	1,637.73	142.32	71.16	71 16	3 28
kg/h of dissolved solids	36,395.6	1.7	36,393.93	3,639.39	32,754.54	29,479.08	3,275.45	1,637.73	1,637.73	131.02	65.51	65 51	2 95
kg/h COD	36,403.0	8.7	36,394.3	3,639.4	32,754.9	73,698.5	3,275.5	1,637.7	1,637.7	131.02	65.51	65.51	3 28
mg/l COD	54,469.9	224,280.0	54,460.0	54,460.0	54,460.0	750,000.0	6,509.5	6,509.5	6,509.5	520.8	520.8	520 8	26 0
Bioreactor Loading (kg/m3/d)									12 00			1 00	
Bioreactor Volume (m3)									3,275.45			1,572 22	
COD Reduction									0.92			0 95	
Biogas Production (m3/d)									8,859.45			0 00	

Case 3- Mass Balance - Combined Anaerobic (bic Biological Treatment - NREL - Enzymatic

version 3-30-98	Map mass balance												
flow no.	1	2	3	4	5	6	7	8	9	10	11	12	13
flow name	stillage	centrifuge solids	centrifuge liquids	centrifuge backset	feed to next process	evaporator syrup	evaporator condensate	evaporator backset	feed to methanator	methanator effluent	Methanator backset	feed to aerobic treatment	aerobic effluent
flow rate kg/h	307,221.0	17.8	307,203.16	30,720.32	276,482.85	22,394.92	254,087.93	127,043.96	127,043.96	127,043.96	63,521.98	63,521.98	63,521.98
backset (%)	0.0	0.0	0.00	10.00	0.00	0.00	0.00	50.00	0.00	0.00	50.00	0.00	0.00
% TS	2.7	20.2	2.70	2.70	2.70	30.00	0.29	0.29	0.29	0.0255	0.03	0.03	0.001
% Suspended Solids	0.0	18.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0020	0.0020	0.0020	0.0001
%dissolved solids	2.7	0.4	2.70	2.70	2.70	30.00	0.29	0.29	0.29	0.02	0.024	0.024	0.00
% moisture	97.3	79.8	97.30	97.30	97.30	70.00	99.71	99.71	99.71	99.97	99.97	99.97	99.99
kg/h of moisture	298,923.0	14.2	298,908.94	29,890.89	269,018.04	15,676.44	253,341.45	126,670.72	126,670.72	127,011.53	63,505.76	63,505.76	63,515.63
kg/h suspended solids	3.4	3.2	0.17	0.02	0.15	0.15	0.00	0.00	0.00	2.58	1.29	1.29	0.07
kg/h of total solids	8,298.0	3.6	8,294.40	829.44	7,464.96	6,718.48	746.48	373.24	373.24	32.43	16.22	16.22	0.75
kg/h of dissolved solids	8,294.6	0.4	8,294.23	829.42	7,464.80	6,718.32	746.48	373.24	373.24	29.86	14.93	14.93	0.67
kg/h COD	8,298.0	3.6	8,294.4	829.4	7,465.0	16,796.2	746.5	373.2	373.2	29.86	14.93	14.93	0.75
mg/l COD	27,009.9	202,058.0	26,999.7	26,999.7	26,999.7	750,000.0	2,937.9	2,937.9	2,937.9	235.0	235.0	235.0	11.8
Bioreactor Loading (kg/m3/d)									12.00			1.00	
Bioreactor Volume (m3)									746.48			358.31	
COD Reduction									0.92			0.95	
Biogas Production (m3/d)									2,019.08			0.00	

Appendix B

Comparison of Four Alternatives

NREL - Ethanol WWT Options

		Stream #	Flow, MGD	MGY	M#/Year	MM$/Year
A	Direct Evaporation	5	270	98710	822254	$ 1.990
B	Direct Stream Discharge		270	requires Denver Regional size plant		
C	Direct Land Application		270			$ 30
D	Discharge to POTW		270			$ 368
E	Direct Evaporation	9	122	44419	370014	$ 895
F	Direct Stream Discharge		122	requires Denver city sized plant		
G	Direct Land Application		122			$ 13
H	Discharge to POTW		122			$ 166
I	Direct Evaporation	13	61	22210	185007	$ 448
J	Direct Stream Discharge		61	requires		
K	Direct Land Application		61			$ 7
L	Discharge to POTW		61			$ 83

A, E, & I Direct Evaporation
1100 Btu per #
$ 2.20 per MMBtu
$ 2.420 per MM# fuel cost only

B, F, & J Direct Stream Discharge
requires meeting spec of 30 mg/L of BOD and TSS
requires treatment equivalent to a regional or large city treatment plant
(or dilution with inordinate volumes of fresh water - if allowed)

C, G, & K Direct Land Application
665 acres required for 1 MGD **Evaporati** Capital @ 8.00%
input => $ 1.800 per acre purchase and improvement c $ 1,197,000
input => $ 200 per acre tax + O&M per year Term
$169.75 P&I minus future value per acre per year 20 years
$245.886 per 1 MGD per year

Fut. Value
Direct Land Application 0.00% after
300 acres required for 1 MGD **Irrigation** sludge
$ 1.800 per acre purchase and improvement c $ 540,000
$ 200 per acre tax + O&M per year 60000
$169.75 P&I minus future value per acre per year
$110.926 per 1 MGD per year
($183.33)

D. H & L	Discharge to POTW	
	Use Enzymatic as Basis (lowest cost)	
	for 1 MGD, annual cost is	$ 1,361,000

NREL Ethanol Waste Water Treatment
June 18, 1998 Rev. B

Costs for POTW Treatment of Waste Water

Per Denver Metro example costs (1997):

The cost for POTW treatment is the sum of the following parameters:

a. $362 per ton of TSS

b. $363 per MGD (monthly charge based on daily average flow)
or $363x12 = $4356 per year per MGD average

c. $375 per ton of BOD_5

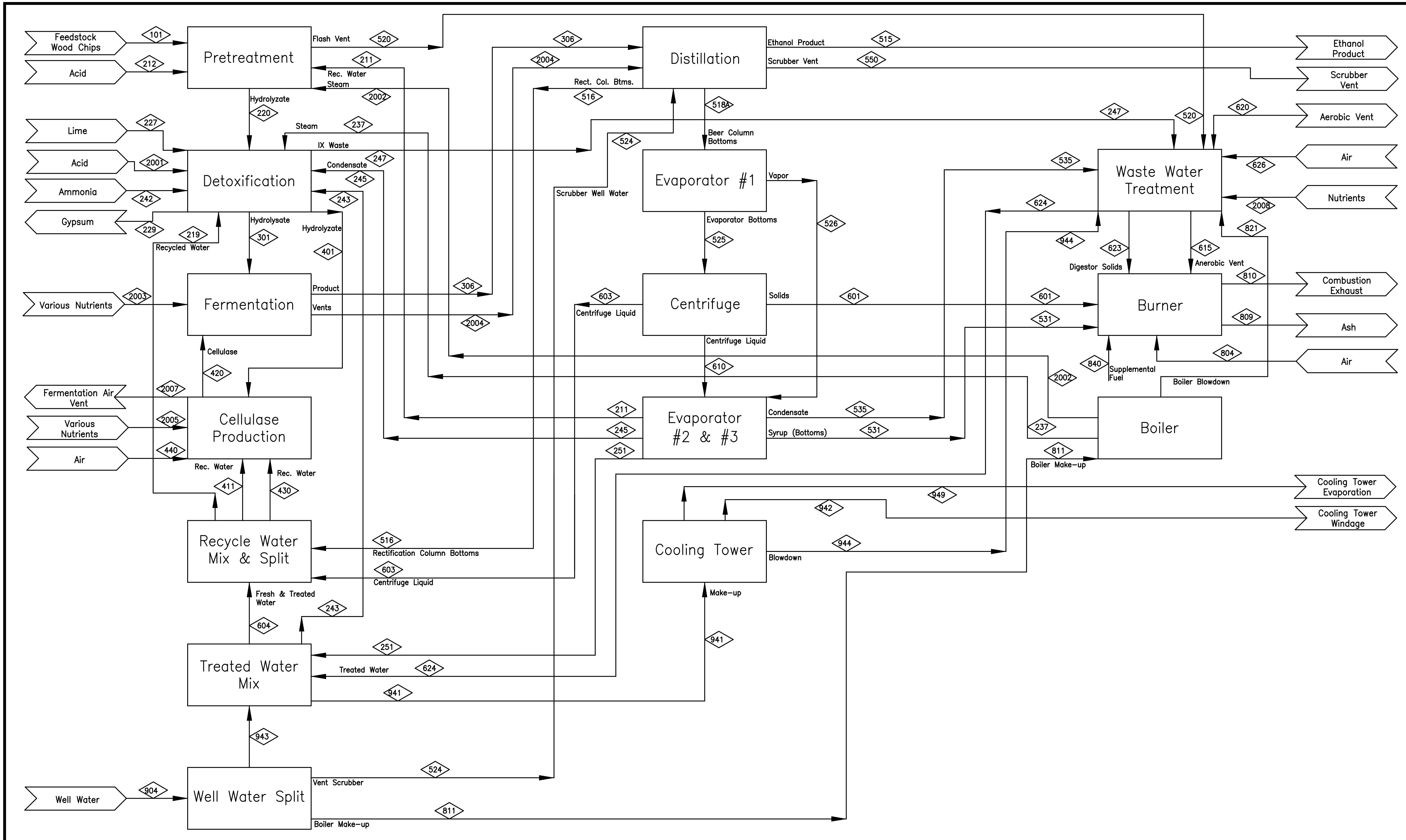
d. $695 per ton of Total Kjeldahl Nitrogen, TKN, (sum of organic and ammonia nitrogen)

These parameters are analysed on the daily average samples taken at the discharge into the POTW stream.

NREL -- Ethanol Waste Water Treatment					
Cost Basis for POTW Treatment of Waste Water					
POTW Costs:					
Case *1x* -- Enzymati	units(daily	cost/unit		Daily Cos	Annual Cost
TSS =	0.045815 tons	$	362	$ 17	
Flow =	1 MGD	$	363	$ 12	
BOD =	9.85248 tons	$	375	$ 3,695	
TKN =	0.01 tons	$	695	$ 7	
bod/cod=0.5				$ 3,730	$ 1,361,565
Case *1y* -- Softwood	units(daily	cost/unit		Daily Cos	Annual Cost
TSS =	3.969245 tons	$	362	$ 1,437	
Flow =	1.4 MGD	$	363	$ 17	
BOD =	19.21392 tons	$	375	$ 7,205	
TKN =	0.01 tons	$	695	$ 7	
				$ 8,666	$ 3,163,081
Case *1z* -- Hardwood	units(daily	cost/unit		Daily Cos	Annual Cost
TSS =	1.95755 tons	$	362	$ 709	
Flow =	2.2 MGD	$	363	$ 27	
BOD =	43.23528 tons	$	375	$ 16,213	
TKN =	0.01 tons	$	695	$ 7	
				$ 16,955	$ 6,188,733

Appendix C

Block Flow Diagram / Water Balance



VER	DESCRIPTION	DATE
A	INITIAL ISSUE	5/98
B	NREL YEAR 2000 CASE	10/98
C	DESIGN REPORT	2/99

LL 2/24/99

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Pretreatment

		Inlets					Outlets			
					2002 = 215 + 216					
COMPONENT	UNITS	101	211	212	215	216	220	520	IN	OUT
Total Flow	kg/hr	159,948	47,518	922	16,907	44,741	224,911	45,124	270,034	270,035
Total Flow	gpm	580	222	1			889			
Insoluble Solids	%	52.1%	0.0%	0.0%	0.0%	0.0%	26.2%	0.0%		
Soluble Solids	%	0.0%	0.3%	0.0%	0.0%	0.0%	9.4%	0.1%		
Percent Water	%	47.9%	98.9%		100.0%	100.0%	62.1%	97.1%		
Water	kg/hr	76,615	47,001		16,907	44,741	139,558	43,810	185,263	183,368

Waste Water Treatment

		Inlets								Outlets					
						2008 = 630 + 631									
COMPONENT	UNITS	247	520	535	626	630	631	821	944	615	620	623	624	IN	OUT
Total Flow	kg/hr	91,967	45,124	13,834	149,904	225	1	6,566	16,488	2,583	152,736	896	167,894	324,109	324,109
Total Flow	gpm	443		64		1	0	44	73			3	743		
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	30.0%	0.0%		
Soluble Solids	%	0.0%	0.1%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
Percent Water	%	94.9%	97.1%	98.9%				100.0%	100.0%	4.4%	1.6%	69.9%	99.8%		
Water	kg/hr	87,291	43,810	13,684				6,566	16,488	113	2,378	626	167,505	167,839	170,622

Detoxification

		Inlets									Outlets					
				2001 = 233 + 235												
COMPONENT	UNITS	219	220	227	233	235	237	242	243	245	229	247	301	401	IN	OUT
Total Flow	kg/hr	132,211	224,911	715	305	642	2,492	1,128	65,191	29,894	2,437	91,967	343,934	19,151	457,489	457,489
Total Flow	gpm	596	889	1	0	1		8	304	139	6	443	1,407	78		
Insoluble Solids	%	0.2%	26.2%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	79.9%	0.0%	16.2%	16.2%		
Soluble Solids	%	1.1%	9.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	1.5%	0.0%	6.3%	6.3%		
Percent Water	%	97.0%	62.1%				100.0%		100.0%	98.9%	18.4%	94.9%	76.4%	76.4%		
Water	kg/hr	128,285	139,558				2,492		65,191	29,569	448	87,291	262,611	14,623	365,095	364,973

Burner

		Inlets						Outlets			
COMPONENT	UNITS	531	601	615	623	804	840	810	809	IN	OUT
Total Flow	kg/hr	48,325	98,808	2,583	897	469,285	1	618,601	1,298	619,899	619,899
Total Flow	gpm	213	377		3				3		
Insoluble Solids	%	2.4%	30.5%	0.0%	30.0%	0.0%	0.0%	0.0%	100.0%		
Soluble Solids	%	9.8%	4.4%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%		
Percent Water	%	79.0%	62.8%	4.4%	69.9%	1.0%		23.3%			
Water	kg/hr	38,167	62,056	113	626	4,693		143,990		43,599	143,990

Fermentation

		Inlets						Outlets				
			2003 = 310 + 310A + 311 + 311A					2004 = 304C + 308				
COMPONENT	UNITS	301	310	310A	311	311A	420	304C	308	306	IN	OUT
Total Flow	kg/hr	343,934	8	584	129	960	39,211	876	16,979	366,970	384,826	384,825
Total Flow	gpm	1,407		3		4	169			1,565		
Insoluble Solids	%	16.2%	0.0%	0.0%	0.0%	0.0%	5.6%	0.0%	0.0%	8.6%		
Soluble Solids	%	6.3%	0.0%	100.0%	0.0%	100.0%	1.7%	0.0%	0.0%	3.1%		
Percent Water	%	76.4%					90.5%	1.7%	1.7%	80.4%		
Water	kg/hr	262,611					35,474	15	288	295,226	298,085	295,529

Boiler

		Inlet	Outlets					
			2002 = 215 + 216					
COMPONENT	UNITS	811	215	216	237	821	IN	OUT
Total Flow	kg/hr	70,748	16,907	44,741	2,492	6,613	70,748	70,752
Total Flow	gpm	312				44		
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%		
Soluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%		
Percent Water	%	100.0%	100.0%	100.0%	100.0%	100.0%		
Water	kg/hr	70,748	16,907	44,741	2,492	6,613	70,748	70,752

Cellulase

		Inlets									Outlets				
					2005 = 416 + 417 + 423 + 434 + 436							2007 = 419 + 435			
COMPONENT	UNITS	401	411	430	416	417	423	434	436	440	420	419	435	IN	OUT
Total Flow	kg/hr	19,151	22,766	2,146	580	227	30	8	157	322,922	39,211	307,281	21,494	367,986	367,986
Total Flow	gpm	78	103	10	3	1	0				169				
Insoluble Solids	%	16.2%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.6%	0.0%	0.0%		
Soluble Solids	%	6.3%	1.1%	1.1%	69.9%	0.0%	100.0%	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%		
Percent Water	%	76.4%	97.0%	97.0%							90.5%	1.4%	2.3%		
Water	kg/hr	14,623	22,090	2,082							35,474	4,263	501	38,794	40,238

Trreated Water Mix

		Inlets			Outlets				
COMPONENT	UNITS	251	624	943	243	604	941	IN	OUT
Total Flow	kg/hr	47,098	167,894	112,929	65,191	81,215	181,370	327,921	327,776
Total Flow	gpm	220	743	503	304	359	807		
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
Soluble Solids	%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%		
Percent Water	%	98.9%	99.8%	100.0%	100.0%	100.0%	100.0%		
Water	kg/hr	46,586	167,505	112,929	65,191	81,215	181,370		

Recycle Water Mix and Split

		Inlets			Outlets				
		Inlets			Outlets				
COMPONENT	UNITS	516	603	604	219	411	430	IN	OUT
Total Flow	kg/hr	30,943	44,965	81,215	132,211	22,766	2,146	157,123	157,123
Total Flow	gpm	152	199	359	596	103	10		
Insoluble Solids	%	0.0%	0.9%	0.0%	0.2%	0.2%	0.2%		
Soluble Solids	%	0.7%	3.5%	0.0%	1.1%	1.1%	1.1%		
Percent Water	%	96.4%	92.1%	100.0%	97.0%	97.0%	97.0%		
Water	kg/hr	29,822	41,420	81,215	128,285	22,090	2,082		

Well Water

		Inlet	Outlets				
COMPONENT	UNITS	904	524	811	943	IN	OUT
Total Flow	kg/hr	196,676	13,042	70,705	112,929	196,676	196,676
Total Flow	gpm	874	57	312	503		
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%		
Soluble Solids	%	0.0%	0.0%	0.0%	0.0%		
Percent Water	%	100.0%	100.0%	100.0%	100.0%		
Water	kg/hr	196,676	13,042	70,705	112,929		

Cooling Tower

		Inlet	Outlets				
COMPONENT	UNITS	941	942	944	949	IN	OUT
Total Flow	kg/hr	181,370	10,655	16,488	154,227	181,370	181,370
Total Flow	gpm	807	47	73			
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%		
Soluble Solids	%	0.0%	0.0%	0.0%	0.0%		
Percent Water	%	100.0%	100.0%	100.0%	100.0%		
Water	kg/hr	181,370	10,655	16,488	154,227		

Distillation

		Inlets				Outlets					
			2004 = 304C + 308								
COMPONENT	UNITS	306	304C	308	524	515	516	518A	550	IN	OUT
Total Flow	kg/hr	366,970	876	16,979	13,042	18,565	30,943	330,442	17,917	397,867	397,867
Total Flow	gpm	1,565			57	108	152	1,502			
Insoluble Solids	%	8.6%	0.0%	0.0%	0.0%	0.0%	0.0%	9.6%	0.0%		
Soluble Solids	%	3.1%	0.0%	0.0%	0.0%	0.0%	0.7%	3.3%	0.0%		
Percent Water	%	80.4%	1.7%	1.7%	100.0%	0.5%	96.4%	84.3%	1.0%		
Water	kg/hr	295,226	15	288	13,042	92	29,822	278,485	173	308,571	308,572

Evaporator #1

		Inlet	Oultets			
COMPONENT	UNITS	518A	525	526	IN	OUT
Total Flow	kg/hr	330,442	278,666	51,776	330442	330442
Total Flow	gpm	1,502	1,213			
Insoluble Solids	%	9.6%	11.4%	0.0%		
Soluble Solids	%	3.3%	3.8%	0.7%		
Percent Water	%	84.3%	81.7%	98.0%		
Water	kg/hr	278,485	227,738	50,747	278485	278485

Centrifuge

		Inlets	Outlets				
COMPONENT	UNITS	525	601	603	610	IN	OUT
Total Flow	kg/hr	278,666	98,808	44,965	134,894	278,666	278,667
Total Flow	gpm	1,213	377	199	596		
Insoluble Solids	%	11.4%	30.5%	0.9%	0.9%		
Soluble Solids	%	3.8%	4.4%	3.5%	3.5%		
Percent Water	%	81.7%	62.8%	92.1%	92.1%		
Water	kg/hr	227,738	62,056	41,420	124,261	227,738	227,738

Evaporators 2 & 3

		Inlets		Outlets						
COMPONENT	UNITS	526	610	211	251	245	531	535	IN	OUT
Total Flow	kg/hr	51,776	134,894	47,518	47,098	29,894	48,325	13,834	186,670	186,669
Total Flow	gpm		596	222	220	139	213	64		
Insoluble Solids	%	0.0%	0.9%	0.0%	0.0%	0.0%	2.4%	0.0%		
Soluble Solids	%	0.7%	3.5%	0.3%	0.3%	0.3%	9.8%	0.3%		
Percent Water	%	98.0%	92.1%	98.9%	98.9%	98.9%	79.0%	98.9%		
Water	kg/hr	50,747	124,261	47,001	46,586	29,569	38,167	13,684	175,008	175,008

Overall Balance

		Inlets																		
					2001 = 233 + 235			2003 = 310 + 310A + 311 + 311A					2005 = 416 + 417 + 423 + 434 + 436							
COMPONENT	UNITS	101	212	227	233	235	242	310	310A	311	311A	440	416	417	423	434	436	904	626	804
Total Flow	kg/hr	159,948	922	715	305	642	1,128	8	584	129	960	322,922	580	227	30	8	157	196,676	149,904	469,324

Overall Balance

		Outlets											
COMPONENT	UNITS	229	419	435	515	550	620	810	809	949	942	IN	OUT
Total Flow	kg/hr	2,437	307,281	21,494	18,565	17,917	152,740	618,601	1,298	155,326	10,731	1,306,305	1,306,390

VER	DESCRIPTION	DATE
A	INITIAL ISSUE	5/98
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		LL 2/24/99

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SECTION A600
Overall Water Balance

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Appendix D

Reasons for Anaerobic / Aerobic Process Selection

APPENDIX D

PHOENIX BIO-SYSTEMS, INC.

at ICM, Inc.:

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ANAEROBIC BIO-REACTORS FOR HIGH PERFORMANCE WASTEWATER TREATMENT IN BIOMASS TO ETHANOL OPERATIONS

Industrial Wastewater

Waste "strength" may be measured by five (5) day Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD) or Total Organic Carbon (TOC). Any of these reflect the amount of carbon requiring removal in a given waste water. Chemical Oxygen Demand (COD) describes the amount of oxygen required to completely oxidize all waste (primarily carbon) to CO_2 and is usually used to describe the efficiency of biomethanation.

Waste water streams vary in strength from a few hundred milligrams per liter (mg/l) COD to hundreds of thousands of mg/l COD. Some examples of waste waters are:

TYPE OF WASTE	COD
Municipal Waste Waters	150 - 300 mg/l
Cheese Plant Wash Waters	2,000 - 5,000 mg/l
Cheese Whey	~ 60,000 mg/l
Cheese Whey Permeate	50,000 - 100,000 mg/l
Waste Beer	~ 60,000 mg/l
Brewery Wash Waters	~ 2,000 mg/l
Soft Drink Processing Waste Waters	~ 20,000 mg/l
Potato Processing Waste Water	~ 10,000 mg/l
Vegetable Processing Brine Waste	~ 10,000 mg/l
Oil Operations Waste Water	10,000 - 100,000 mg/l
Winery Waste Water	~ 20,000 mg/l
Can Manufacture (Solvent) Waste	~ 100,000 mg/l

Pharmaceutical Waste Water	10,000 - 100,000 mg/l
Airport Deicer Run-off	10,000 - 300,000 mg/l
Fuel Alcohol Plant Condensate	1,000 - 5,000 mg/l
Distillery Bottoms Water	~ 30,000 mg/l

The list above shows that most industrial waste waters carry far greater organic loading than does municipal sewage. Most of these waste waters are extremely expensive to treat by conventional methods and many industrial manufacturers incur high surcharge costs for discharge to POTW's (Publicly Owned Treatment Works), or in some cases may be banned from public discharge because of the unacceptable loading.

Fuel ethanol operations, whether grain or biomass based, will produce either still bottoms, centrifugate, or evaporator condensate, depending upon the design of the distillery, which will carry high organic waste loads. Centrifuges have been used for the separation of suspended solids from still bottoms, and evaporators have been used for the recovery of most dissolved solids from centrifugate in grain based fuel ethanol plants. In spite of these conservation methods, these plants produce evaporator condensate wastewater, which will usually have COD concentrations of over 1,000 mg/l, and often as high as 5,000 mg/l.

In a biomass-based fuel ethanol plant, non-fermentable solids will be significant, resulting in still bottoms carrying a very high organic load. Even if centrifugation and/or evaporation are applied, wastewater streams from these plants will be very high in COD. In many cases, biomass plants may be located too distant from a POTW for access and in others, loading is likely to be greater than a local POTW can accommodate.

Anaerobic bio-methanation provides a logical and cost-effective means of addressing these wastewaters.

Advantages of Anaerobic Systems

Biomethanation describes the production of biogas by certain micro-organisms using organic (carbonaceous) substances under anaerobic conditions. Biogas consists of a mixture of methane (CH_4) and carbon dioxide (CO_2). The production of methane gas represents a bio-thermodynamic conservation of energy. That is, the energy present in dissolved organic waste is conserved as methane

Figure 1 depicts the metabolic pathways involved in the breakdown of complex organic molecules in the methanogenic conversion process. Three (3) groups of micro-organisms are involved in the methanogenic consortium, hydrolytic bacteria, acetogenic bacteria, and finally, methanogenic bacteria. A number of researchers believe that other micro-organisms, such as sulfate reducing bacteria and hydrogen producing bacteria, may also contribute to the methanogenic consortiums' activity.

Bio-methanation will produce less than ten (10) percent of the waste sludge that is produced by activated sludge or aerobic biological waste water treatment methods. Further, bio-methanation requires only a fraction of the operating horsepower and facility space. Furthermore, the production of biogas offers an energy source which can be utilized in the operating plant to supplement natural gas.

The attached analysis (Table 1) compares the operating costs of bio-methanation verses conventional aerobic treatment for the same hypothetical wastewater. Note that the horsepower, chemical and sludge management costs for the aerobic treatment system are significantly higher. In addition, the aerobic facility would be much larger and more operator and maintenance intensive. Thus, the application of anaerobic treatment technology provides a significant savings opportunity for the removal of most dissolved organic compounds.

General Anaerobic System Description

Anaerobic bio-methanation is not a new concept in wastewater treatment. This technique has been used for over a century in municipal wastewater plants for the digestion and stabilization of waste sludges. These anaerobic digesters are today known as low-rate solids digesters. Although the same biochemical reactions are employed, the digestion of suspended solids requires a much longer residence time than is required in modern high-rate systems. The slow growing anaerobic consortium is an advantage with respect to sludge (bio-solids) generation, however, in high-rate systems it is necessary to maintain the slow growing culture in a reactor to achieve efficient performance.

The first of these modern technologies, known as upflow anaerobic sludge blanket technology (UASB), was pioneered in the Netherlands in the 1970's. This technique takes advantage of a granulated anaerobic sludge or bio-culture, which remains fixed in the base of a reactor while wastewater containing dissolved organic matter is passed upward through the sludge bed. The success of this technology has led to further refinements in the form of expanded-bed and fluid bed systems. At the same time, packed-bed systems have also been developed, which rely on a matrix of plastic or other heavier-than-water material to act as a surface for colonization by anaerobic cultures. The objective in all these systems is really the same; retain high concentrations of active anaerobic biomass in the reaction zone.

The result of these technological developments is that several manufacturers world-wide, produce and market high-rate anaerobic treatment systems for the removal of dissolved organics from waste water. These high-rate systems operate reliably with hydraulic retention times as low as four (4) hours. Most obtain eighty (80) to ninety-five (95) percent reduction of COD.

A general system flow would include: equalization, recirculated fluid mixing, the anaerobic reactor, nutrient supplementation systems, pH, temperature, and flow control systems, and bio-gas scrubbing, management, and flaring systems.

Diagram 1 represents a general flow for the application of biomethanation and aerobic polishing for a typical fuel ethanol plant. Where COD or BOD_5 are very high and discharge limits are very low for these parameters, both anaerobic and aerobic systems may be required. That is, where more than ninety (90) percent COD reduction is required for discharge, aerobic polishing of the waste water is needed but will be far less expensive as it addresses only a fraction of the original waste load.

Biogas Production

In conventional biomethanation systems, biogas will range from fifty-five (55) to seventy (70) percent methane (CH_4), the remainder being carbon dioxide (CO_2) . Maximum theoretical methane yield is 0.35 liters of methane per gram of COD converted.

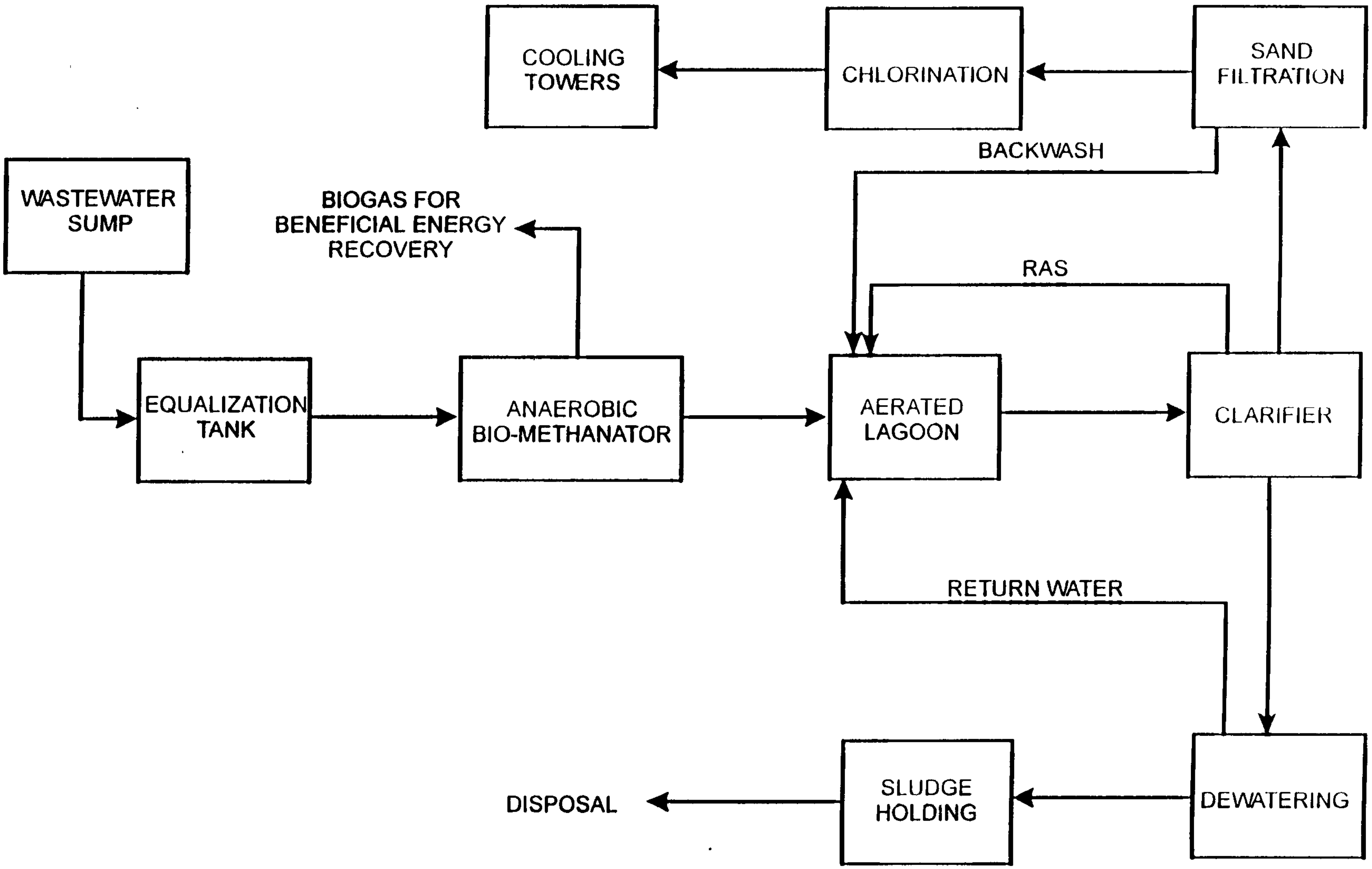
In many high-rate systems, methane averages over eighty-five (85) percent in biogas. This is thought to be due to the differences associated with solids digestion and the digestion of dissolved organic compounds. One manufacturer, who uses a proprietary carbon dioxide removal system, routinely reports methane concentrations in-excess of ninety (90) percent.

Most commercial systems utilize emergency flare equipment, which are based upon system pressures. When economically feasible, biogas will be utilized in boilers, natural gas dryers, and sometimes in internal combustion engines to generate electricity. In these cases, emergency flares are only used when biogas production exceeds requirements.

Since these biological systems operate optimally at temperatures between eighty-five (85) and one hundred (100) degrees Fahrenheit, some of the biogas produced may be used to heat the reactors through the use of simple gas fired hot water heaters.

In grain-based fuel ethanol plant applications, where bio-methanators have been used to treat hot (160 to 200° F) evaporator condensate prior to discharge, cooling of the condensate stream is required. In these applications, all of the produced biogas has been used as supplemental spent grain dryer fuel. In biomass based fuel ethanol plants, it is unlikely that spent grain dryers will be employed. Therefore, biogas may be used as supplemental boiler fuel.

COMBINED ANAEROBIC-AEROBIC BIOLOGICAL TREATMENT



PROCESS FLOW DIAGRAM #1

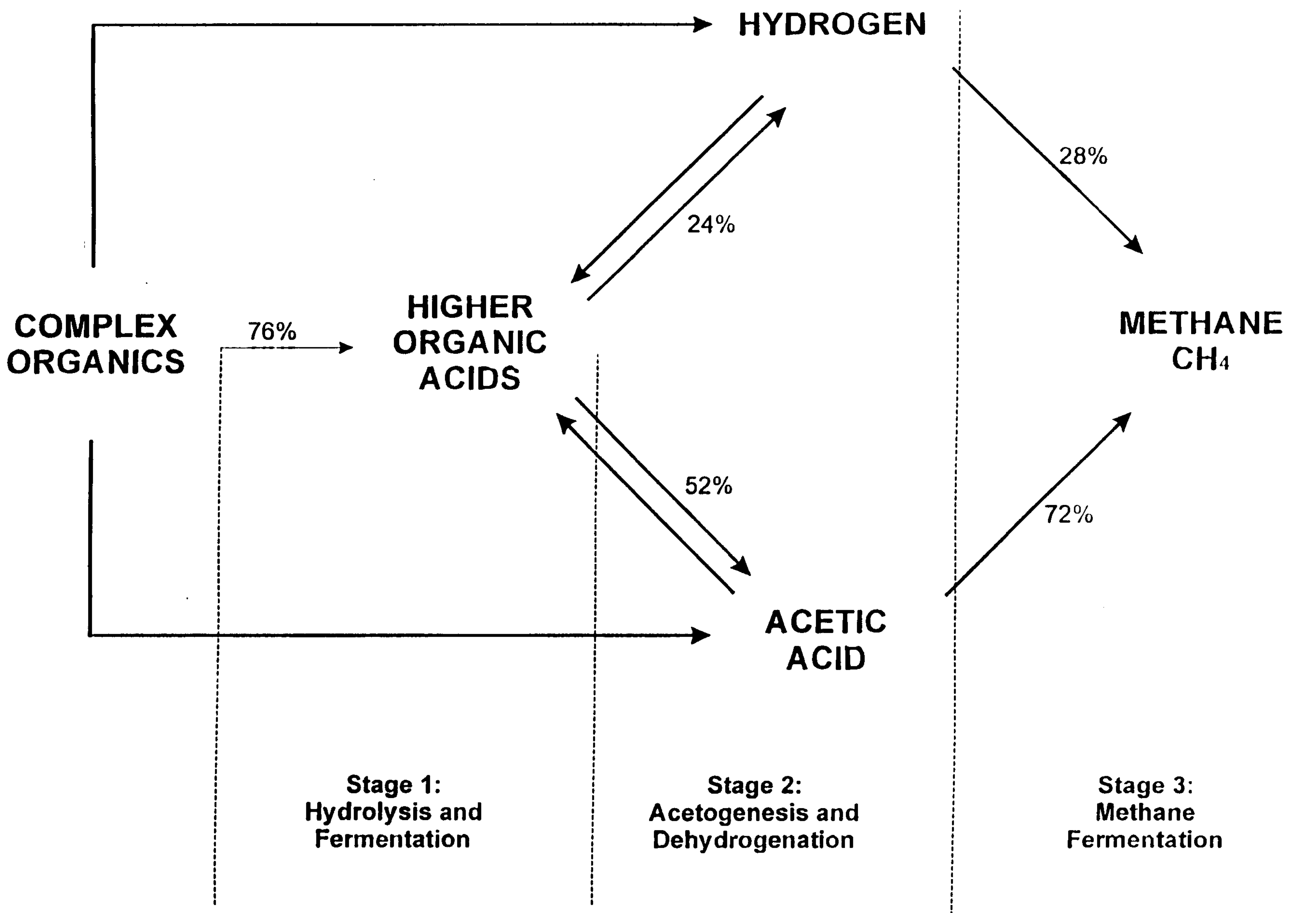


Figure 1 **Steps in the anaerobic digestion process**

Table 1 - Anaerobic Aerobic Treatment -

Anaerobic Treatment followed by Aerobic Bio-Tower

PARAMETERS	ANAEROBIC BIO-METHANATOR AMOUNTS	ANAEROBIC BIO-METHANATOR DAILY COST	AEROBIC ACTIVATED SLUDGE TREATMENT AMOUNTS	AEROBIC ACTIVATED SLUDGE TREATMENT DAILY COST
Flow, Gallons Per Minute (GPM)	300.00		300.00	
Flow, Gallons Per Day (GPD)	432,000.00		432,000.00	
Chemical Oxygen Demand (COD) mg/l	3,000.00		3,000.00	
Biological Oxygen Demand (BOD_5) mg/l	2,100.00		2,100.00	
Pounds Per Day COD	10,804.76		10,804.76	
Pounds Per Day BOD	7,563.33		7,563.33	
Inlet Temperature	25C		37C	
Total Nitrogen mg/l	0.00		0.00	
Total Phosphate mg/l	0.00		0.00	
COD Space Loading Rate g/l/d	12.00		0.75	
COD Reduction	0.90		0.90	
Residual COD mg/l	300.00		300.00	
Horsepower Required:				
Blower Horsepower	3.00		675.30	
Pumping & Other Horsepower	80.00		150.00	
Total Horsepower	83.00		825.30	
Cost per kwh	0.05		0.05	
Kwh per day	1,474.08	$73.70	14,657.28	$732.86
Chemicals Required, lbs/day:				
Nitrogen	29.17	$5.83	388.97	$77.79
Phosphate	9.72	$1.56	129.66	$20.75
Micro-Nutrients	1.62	$0.81	21.61	$6.48
Caustic lbs/day Required	540.24	$102.65	0.00	$0.00
Polymer @ $ 2.50/lb	0.00	$0.00	10.00	$25.00
Chlorine			0.00	$0.00

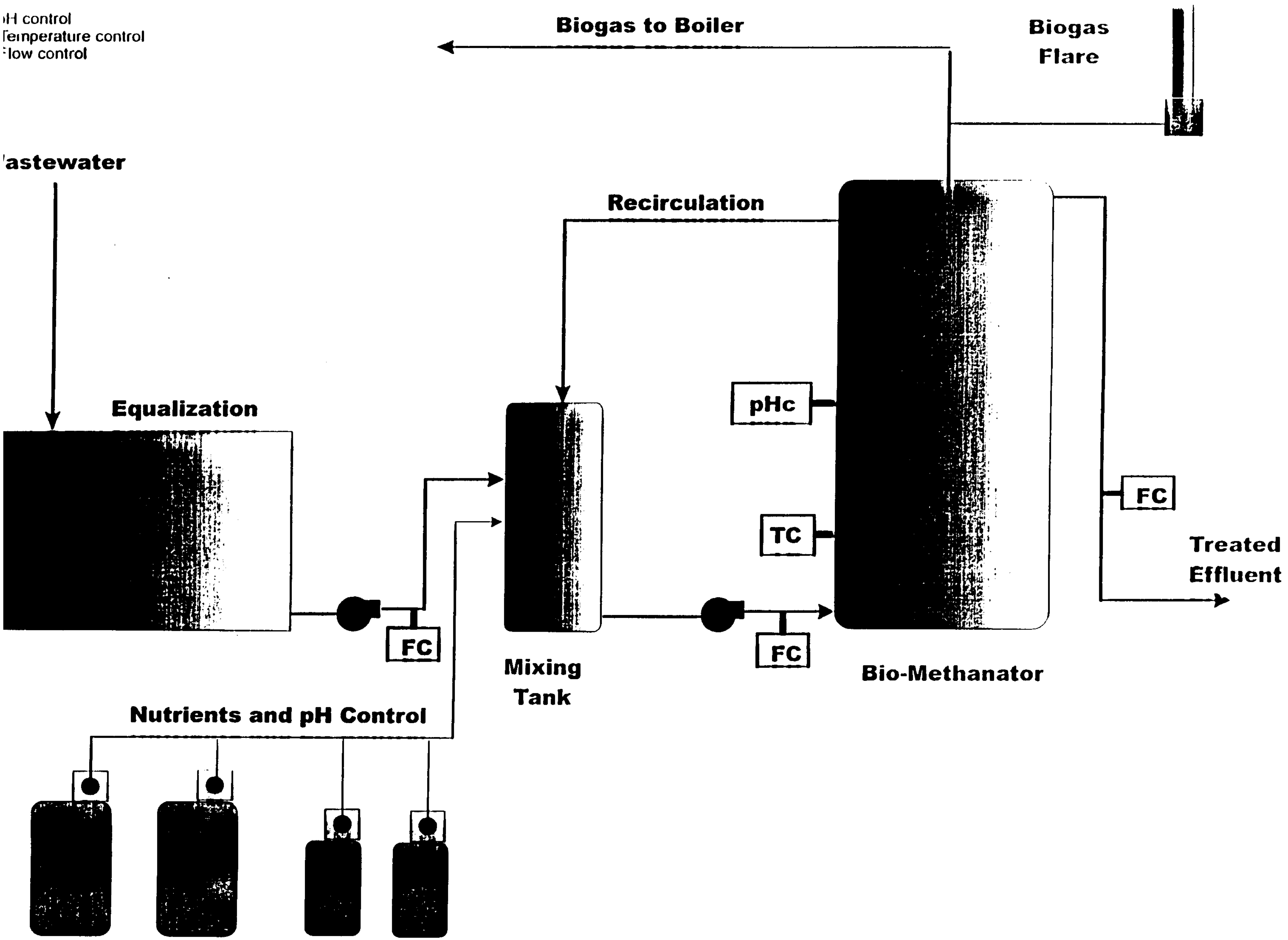
Table 1 - Anaerobi… …erobic Treatment -

PARAMETERS	AMOUNTS	DAILY COST	AMOUNTS	DAILY COST
Sludge (Biomass) Generation:				
Dry Weight Yield, lbs/day	324.14		4,321.90	
Wet Weight of Sludge, lbs/day	6,482.85		432,190.31	
Sludge Total Solids	5%		1%	
Sludge Yield on COD	3%		40%	
Sludge Disposal :				
Dewatering @ $ 0.XX per 1000 lb wet weight	0.03	$1.94	0.03	$129.66
Volume Reduction	80%		80%	
Disposal Volume	155.28		10,351.86	
Disposal @ $ 0.0X/gal	0.03	$4.66	0.03	$310.56
Bio-Gas Produced (CFD):	55,813.64		0.00	
Methane Yield (85%) CFD	47,441.59		0.00	
Less Heating Requirement	4,000.00			
Net Methane for energy	43,441.59			
Bio-Gas Credit ($2.50/MMBTU Methane)		($108.60)	0.00	$0.00
Labor:				
Cost per hour ($)	12.00		12.00	
Manhours / Day	2.00	$24.00	16.00	$192.00
Maintenance parts	25.00	$30.00	50.00	$60.00
Sewer Surcharge:				
Flow @ $0.XX /1000 gal	0.50	$216.00	0.50	$216.00
Allowable BOD Concentration mg/l	300.00		300.00	
BOD @ $0.XX /lb in excess	0.00	$0.00	0.00	$0.00
Allowable TSS Concentration mg/l	250.00		250.00	
TSS @ $0.XX /lb	0.00	$0.00	0.00	$0.00

Table 1 - Anaerobi[illegible] [illegible]erobic Treatment -

Total Daily Cost		**$352.55**		**$1,771.10**	
Annual Cost (Days per year)	**350.00**	**$123,392.23**	**350.00**	**$619,884.76**	
Net Annual Cost Difference					**$496,492.53**

PARAMETERS	**AMOUNTS**	**AMOUNTS**
Unit Operations Required:		
Equalization Tank (gal)	86,400.00	86,400.00
Main Reactor Size (gal)	108,000.00	1,728,000.00
Clarifier (gal)	N/A	90,000.00



ıH control
Temperature control
Flow control
Biogas to Boiler
Biogas
Flare
'astewater
Recirculation
pHc
Equalization
FC
TC
Treated
Effluent
FC
FC
Mixing
Tank
Bio-Methanator
Nutrients and pH Control

Appendix E

NREL Ethanol Waste Water Treatment

Design Basis for Alternative Waste Water Treatment Systems

		Enzymatic	Softwood	Hardwood
Daily Average Flow	MGD	1	1.4	2.2
Design Daily Peak Flow	MGD	2	2.8	4.4
Design Weekly Peak Flow	MGD	1.8	2.52	3.96
Design Monthly Peak Flow	MGD	1.5	2.1	3.3
Design Annual Peak Flow	MGD	1.25	1.75	2.75
Daily Average TSS				
		use similar factors for peak flows		
Daily Average BOD				
Daily Average TKN				

Appendix F

Cost Estimates

Equipment Summary								
Eq No.	Eq Description	Drawing	Mat. C	No.	Unit	Total Pur	I Fact	Installed
A-602	Equalization Basin Agitator	A602	SS	1	$28,400	$28,400	1.2	$34,080
A-606	Anerobic Digestor Agitator	A602	SS	4	$30,300	$121,200	1.2	$145,440
A-608	Aerobic Digestor Aerator	A603	CS	16	$31,250	$500,000	1.4	$700,000
A-630	Recycle Water Tank Agitator	A601	CS	1	$5,963	$5,963	1.3	$7,752
C-601	Lignin Wet Cake Screw	A601	CS	1	$31,700	$31,700	1.4	$44,380
C-614	Aerobic Sludge Screw	A603	CS	1	$5,700	$5,700	1.4	$7,980
H-602	Anerobic Digestor Feed Cooler	A602	SS	1	$175,000	$175,000	2.1	$367,500
M-604	Nutrient Feed System	A602	CS	1	$31,400	$31,400	2.58	$81,012
M-606	Biogas Handling System	A602	SS	1	$20,739	$20,739	1.68	$34,842
M-612	Filter Aid Addition System	A603	CS	1	$3,000	$3,000	1.2	$3,600
P-602	Anerobic Digestor Feed Pump	A602	CS	2	$11,400	$22,800	2.8	$63,840
P-606	Aerobic Digestor Feed Pump	A602	CS	2	$10,700	$21,400	2.8	$59,920
P-608	Aerobic Sludge Recycle Pump	A603	SS316	1	$11,100	$11,100	2.8	$31,080
P-610	Aerobic Sludge Pump	A603	SS316	1	$11,100	$11,100	2.8	$31,080
P-611	Aerobic Digestion Outlet Pump	A603	CS	2	$10,700	$21,400	2.8	$59,920
P-614	Sludge Filtrate Recycle Pump	A603	CS	2	$6,100	$12,200	2.8	$34,160
P-616	Treated Water Pump	A603	CS	2	$10,600	$21,200	2.8	$59,360
P-630	Recycle Water Pump	A601	CS	2	$10,600	$21,200	2.8	$59,360
S-600	Bar Screen	A602	CS	1	$111,541	$111,541	1.2	$133,849
S-601	Beer Columns Bottoms Centrifuge	A601	SS316	3	$659,550	$1,978,650	1.2	$2,374,380
S-614	Aerobic Sludge Belt Filter Press	A603	?	1	$650,223	$650,223	1.8	$1,170,401
T-602	Equalization Basin	A602	Concrete	1	$350,800	$350,800	1.42	$498,136
T-606	Anerobic Digestor	A602	Lined or ss	4	$881,081	$3,524,324	1.04	$3,665,297
T-608	Aerobic Digestor	A603	Lined Pit	1	$635,173	$635,173	1	$635,173
T-610	Clarifier	A603	Concrete	1	$174,385	$174,385	1.96	$341,795
T-630	Recycle Water Tank	A601	CS	1	$14,515	$14,515	1.4	$20,321
						$8,505,113	1.25	$10,664,657

```
Equipment Num         :: A-602
Eqipment Name         :: Equalization Basin Agitator
Associated PFD        :: PFD-P100-A602
Equipment Type        :: FIXED-PROP
Equipment Category    :: AGITATOR
Equipment Description:: 38 hp each, Fixed Prop, 0.1 hp/1000 gal
Number Required       :: 1
Number Spares         :: 0
Scaling Stream        :: 612
Base Cost             :: 28400.00
Cost Basis            :: ICARUS
Cost Year             :: 1997
Base for Scaling      :: 188129.000
Base Type             :: FLOW
Base Units            :: KG/HR
Install. Factor       :: 1.2000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.5100
Scale Factor Basis    :: GARRETT
Material of Const     :: SS
Utility Calc.         :: ASPEN FORT BLCK
Utility Stream        :: WT602
Utility Type          :: POWER
Date Modified         :: 12/21/98
Notes                 :: Expected Power Req: 28 kW.
```

Eq. No.	A-602		
Eq. Name	Equalization Basin Agitator		
Associated PFD	A602		
Stream for Design	612		
Stream Description	Tank Inlet		
Flow Rate	188129	Kg/hr	R9809G
Average Density	0.945	g/CC	R9809G
Flowrate	876	gpm	
Flowrate	52578	gph	
Calculated Tank Vol.	377516	gal	See T-602
Hp Specification	0.1	hp/1000 gal	Assumption
Hp Requirement	38	hp/1000 gal	
Cost ICARUS '97	**$ 28,400**	**SS**	
	$ 27,300	**CS**	
Scaling Stream	612		
Scaling Rate	188129		
Scaling Units	Kg/hr		

A-602 AG - 100 A-602

COMPONENT DATA SHEET

FIXED PROP

CODE OF ACCOUNT: 134

COMPONENT DESIGN DATA:

MATERIAL SS
DRIVER SPEED 1800.00 RPM
DRIVER POWER 38.00 HP
TOTAL WEIGHT 2600 LBS

COST DATA:

ESTIMATED PURCHASE COST USD 28400.

	MATERIAL USD	MANPOWER USD	MANPOWER MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	28400.	842.	48	0.030
PIPING	0.	0.	0	0.000
CIVIL	0.	0.	0	0.000
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	0.	0.	0	0.000
ELECTRICAL	427.	697.	35	1.631
INSULATION	0.	0.	0	0.000
PAINT	0.	0.	0	0.000
SUBTOTAL	28827.	1539.	83	0.053

INSTALLED DIRECT COST 30400. INST'L COST/PE RATIO 1.070

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 17NOV98-12:38:36

```
Equipment Num         :: A-606
Eqipment Name         :: Anaerobic Agitator
Associated PFD        :: PFD-P100-A602
Equipment Type        :: FIXED-PROP
Equipment Category    :: AGITATOR
Equipment Description:: Fixed Prop, 41 hp, 0.05 hp/1000 gal
Number Required       :: 4
Number Spares         :: 0
Scaling Stream        :: ANEROVOL
Base Cost             :: 30300.00
Cost Basis            :: ICARUS
Cost Year             :: 1997
Base for Scaling      :: 810250.000
Base Type             :: SIZE
Base Units            :: GAL
Install. Factor       :: 1.2000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.5100
Scale Factor Basis    :: GARRETT
Material of Const     :: SS
Utility Calc.         :: ASPEN FORT BLCK
Utility Stream        :: WT606
Utility Type          :: POWER
Date Modified         :: 12/21/98
Notes                 :: Expected Power Req: 123 kW.  SS ESSENTIALLY THE
                         SAME COST AS CS.  SCALING TO ASPEN CALIBRATES
                         ANEROBIC DIGESTOR VOLUME
```

Eq. No.	A-606		
Eq. Name	Anerobic Digestor Agitator		
Associated PFD	A602		
Design Basis	810250	gal	T-606 Individual Volume
Design Basis	0.05	hp/1000 gal	Assumption, based on the fact that there are very little solids to suspend.
Size	41	hp	
Cost Estimate			
Cost ICARUS '97	**$ 30,300**	**SS**	Use because of minor cost differential
	$ 29,100	**CS**	
Scaling Stream	ANEROVOL		Total volume required per vessel, calculated by ASPEN
Scaling Rate	810250		
Scaling Units	gal		
Integer Number Required	INUMANER		Integer Number of Vessels calculated by ASPEN, based on max volume of 950,000 gal per vessel

A-606 AG - 100 A-606

COMPONENT DATA SHEET

FIXED PROP

CODE OF ACCOUNT: 134

COMPONENT DESIGN DATA:

MATERIAL SS
DRIVER SPEED 1800.00 RPM
DRIVER POWER 41.00 HP
TOTAL WEIGHT 2800 LBS

COST DATA:

ESTIMATED PURCHASE COST USD 30300.

	MATERIAL	MANPOWER		L/M RATIO
	USD	USD	MANHOURS	USD/USD
EQUIPMENT&SETTING	30300.	859.	49	0.028
PIPING	0.	0.	0	0.000
CIVIL	0.	0.	0	0.000
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	0.	0.	0	0.000
ELECTRICAL	427.	697.	35	1.631
INSULATION	0.	0.	0	0.000
PAINT	0.	0.	0	0.000
SUBTOTAL	30727.	1556.	84	0.051

INSTALLED DIRECT COST 32300. INST'L COST/PE RATIO 1.066

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:31:04

```
Equipment Num        :: A-608
Eqipment Name        :: Aerobic Lagoon Agitators
Associated PFD       :: PFD-P100-A603
Equipment Type       :: SURFACE-AERATOR
Equipment Category   :: AGITATOR
Equipment Description:: TWISTER SURFACE AERATOR 50 HP EA
Number Required      :: 16
Number Spares        :: 0
Scaling Stream       :: AEROBCHP
Base Cost            :: 31250.00
Cost Basis           :: VENDOR
Cost Year            :: 1998
Base for Scaling     :: 812.000
Base Type            :: SIZE
Base Units           :: HP
Install. Factor      :: 1.4000
Install. Factor Basis:: MERRICK98
Scale Factor Exponent:: 0.5100
Scale Factor Basis   :: GARRETT
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WT608
Utility Type         :: POWER
Date Modified        :: 12/21/98
Notes                :: Expected Power Req.: 605 kW.
```

Eq. No.	A-608		
Eq. Name	Aerobic Digestor Aerator		
Associated PFD	A603		
Calculated COD	**438**	Kg/hr	Calculated below from R9809G
Caclulated BOD	307	Kg/hr	BOD is 70% of COD, V. Putsche, as reported by J. Rucco
BOD daily	16,204	lb/day	
O2 Requirement	32,408	lb/day	2 lb O2 per lb BOD (Goble Sampson)
hp Requirement	812	hp	Calculation per Goble Sampson
Cost Estimate			
Goble Sampson	$500,000	16 aerators	50 hp each
Scaling Stream	AEROBCHP		
Scaling Rate	812		
Scaling Units	HP		

	Kg/hr	COD Kg/hr	Per R9809G
Mass Flow KG/HR			
Glucose	0.00	0	
Xylose	0.00	1.55434E-08	
Unknown	0.00	0	
Colslds	0.00	0	
Ethanol	3.25	6.78210016	
Arabinose	0.00	0	
Galactose	0.00	0	
Mannose	0.00	0	
Glucose Oligomers	0.00	0	
Cellibiose	0.00	0	
Xylose Oligomers	0.00	0	
Mannose Oligomers	0.00	0	
Galactose Oligomers	0.00	0	
Arabinose Oligomers	0.00	0	
Xylitol	0.00	0	
Furfural	54.04	90.2384834	
HMF	18.21	27.6783336	
Methane	2.49	9.95074	
Lactic Acid	0.05	0.056598506	
Acetic Acid	21.11	22.5878391	
Glycerol	0.00	0.000692483	
Succinic Acid	0.00	5.35041E-05	
Denaturant	0.00	0	
Oil	0.00	6.91765E-06	
Acetate Oligomers	0.00	0	
NH4Acet	245.95	281.1238218	
	345.093	438.4186695	Kg/hr of COD

	Kg COD/Kg	
Glucose	1.07	Per Merrick WWT Report 11/98

Xylose	1.07
Unknown	1.07
Colslds	0.71
Ethanol	2.09
Arabinose	1.07
Galactose	1.07
Mannose	1.07
Glucose Oligomers	1.07
Cellibiose	1.07
Xylose Oligomers	1.07
Mannose Oligomers	1.07
Gaactose Oligomers	1.07
Arabinose Oligomers	1.07
Xylitol	1.22
Furfural	1.67
HMF	1.52
Methane	4
Lactic Acid	1.07
Acetic Acid	1.07
Glycerol	1.22
Succinic Acid	0.95
Denaturant	3.52
Oil	2.89
Acetate Oligomers	1.07
NH4Acet	1.143

GOBLE SAMPSON ASSOCIATES

O ARIZONA	X COLORADO	O MONTANA	O NEW MEXICO	O OREGON	O UTAH	O WASHINGTON
303 East 10th Drive	7076 S Alton Way	1520 Third St NW	4004 Carlisle Blvd NE	19210 SW Martinazzi Ave	3500 S Main St	1420 NW Gilman Rd
	Building F	# C-107	Suite J	Suite 122	Suite 200	Suite 2161
Mesa, AZ 85210	Englewood, CO 80112	Great Falls, MT 59404	Albuquerque, NM 87107	Tualatin, OR 97062	Salt Lake City, UT 84115	Issaquah, WA 98027
(602) 969-3867	(303) 770-6418	(406) 965-2536	(505) 881-8718	(503) 692-4172	(801) 268-8790	(425) 392-0491
(602) 969-4096 FAX	(303) 770-6424 FAX	(406) 965-2520 FAX	(505) 881-9055 FAX	(503) 692-1669 FAX	(801) 268-8792 FAX	(425) 392-9615 FAX

LETTER OF TRANSMITTAL

TO Merrick

Date 11/20/98
Your #
GSA #
Attention Dick Voiles
Re: NREL

WE ARE SENDING YOU the following items: X Attached O Under separate cover

O Shop drawings O Submittals O Plans O O & M Manuals
X Copy of letter O Purchase order O Specification O Other

Copies	Date	No.	Description
1			Aeromix Proposal

THESE ARE TRANSMITTED as checked below:

X For your use O Approved as submitted O Resubmit O copies for approval
O As requested O Approved as noted O Submit O copies for distribution
O For approval O Returned for corrections O Return O Corrected prints
O For review and comment O For signature O Other

REMARKS Due to the elevated loading requirements we have changed aerator design. The "TWISTER" is a low speed surface aerator that has better X-fer eff's

Copy to file.

SIGNED SH
STEVE HANSEN

A FAX TRANSMITTAL FROM:

"Specialists in Aeration and Mixing Equipment"

AEROMIX Systems, Inc.
2611 N. Second Street, Minneapolis, MN 55411
Phone: 612 / 521-8519 • Toll free: 800 / 879-3677 • fax: 612 / 521-1455
Visit us on the internet at www.AEROMIX.com

TO:	FROM:
Steve Hansen	Todd Jacobs, Sales Engineer
COMPANY: Goble Sampson Associates	DATE: November 20, 1998
FAX NUMBER: 303/770-6424	TOTAL NO. OF PAGES INCLUDING COVER: 3
PHONE NUMBER: 303/770-6418	SENDER'S PHONE NUMBER: 612 / 521-8519
REGARDING: NREL	SENDER'S FAX NUMBER: 612 / 521-1455

☐ URGENT ☒ FOR REVIEW ☐ PLEASE COMMENT ☐ PLEASE REPLY ☒ PLEASE RECYCLE

Steve,

Per the attached calculations, they need about 800 horsepower to meet the oxygen demand using the TWISTER Slow Speed Surface Aerator. This is the most efficient mechanical aerator made in terms of oxygen transfer. I recommend installing 16 each 50 hp TWISTER Aerators in the first cell. A complete mix should be maintained along with a minimum of two parts per million residual oxygen level. Please not that this sizing is based upon BOD, not the list of contaminants you sent me.

Budget price for 16 each 50 hp TWISTER float mounted slow speed aerators is $500,000.

Call with questions.

Sincerely,

Todd Jacobs

AERATOR SIZING CALCULATIONS FOR:
National Renewable Energy Lab

Date: 11/20/98

Design Criteria

To convert from mg/l to lbs/day use the following equation:
mg/l x 8.34 lb / 1,000,000 x Daily flow (MGD)

Flow :	1.17	Million Gallons per Day			
BOD demand :	1660	mg/l	converts to:	16198	lbs/day
Total Sus Solids:	200	mg/l	converts to:	1952	lbs/day
TKN :	0	mg/l	converts to:	0	lbs/day

The pond volume is found using the following equation:

V = D/3 (As + Ab + squareroot(As * Ab))
Where:

As = surface area D = water depth
Ab = bottom area V =cell volume in cu.ft.

Detention time is found by dividing volume by daily flow.

	Cell 1		Cell 2		Cell 3	
Width:	300.00	ft.	150.00	ft.		ft.
Length:	600.00	ft.	300.00	ft.		ft.
Depth:	15.00	ft.	12.00	ft.		ft.
Volume:	2129726	cu.ft.	418856	cu.ft.	0	cu.ft.
Capacity:	15930352	Gal	3133043	Gal	0	Gal
Det.time:	13.62	Days	2.68	Days	0.00	Days

Oxygen required for BOD removal

For this application we are using: 2.00 lbs of O2 for each pound of BOD per day (under working conditions). A residual oxygen level of 2.00 mg/l should be maintained in the pond at all times.

BOD Oxygen requirement calculation.

16198 lbs of BOD/day x 2.00 lb of O2/lb BOD = 32396 lb 02/day

TKN Oxygen requirement calculation:

0 lbs of TKN/day x 4.60 lb of O2/lb TKN = 0 lb 02/day

Total Oxygen required per day is the total of the BOD and TKN demands.

32396 lbs/day + 0 lbs/day = 32396 lbs O2 (under field conditions

AERATOR SIZING CALCULATIONS FOR:
National Renewable Energy Lab

Oxygen transfer rates for aerators are reported under standard conditions. In order to make proper comparisons under field conditions, Total Oxygen Requirement (TOR) should be converted to Standard Condition Total Oxygen Requirment (STOR). Conversion from field conditions can be accomplished with the following equation:

$$No = \frac{N}{\dfrac{Beta * Cwalt - Cl}{9.17} * Alpha * 1.024^{(T-20)}}$$

Where:

No = STOR lbs/day

N = TOR lbs/day =	32395.90
Beta = Salinity, surface tension factors =	0.95
Cwalt = Saturation at given altitude and temp =	9.10
Cl = Residual oxygen mg/l =	2.00
Alpha = Oxygen transfer correction factor =	0.85
T = Operating temperature (degrees C)	20

$$= \frac{32395.90}{\dfrac{(0.95 * 9.10) - 2.00}{9.17 \text{ mg/l}} * 0.85 * 1.024^{0}}$$

= 52595 lbs of O2/day

At Std. conditions the TWISTER transfers up to 3 lbs O2/Hp-hr. For this system we are using a transfer rate of 2.70 lb O2/Hp-Hr.

Oxygen Hp = 52595.12 lbs-day / 64.80 lbs/Hp-day = 811.65 Hp

TWISTER™

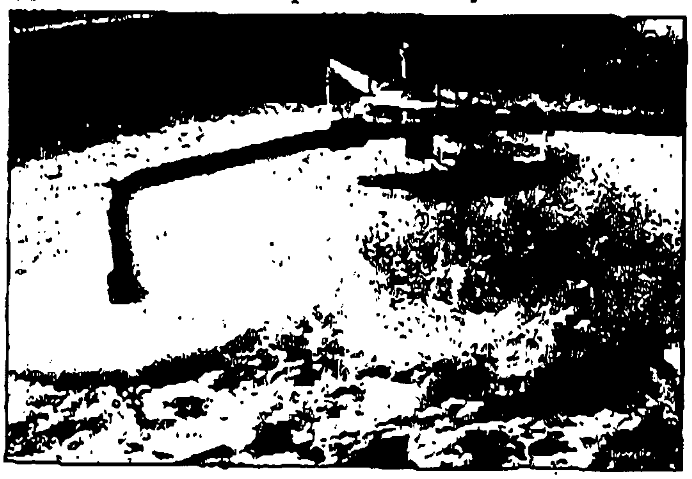
Low Speed Surface Aerator

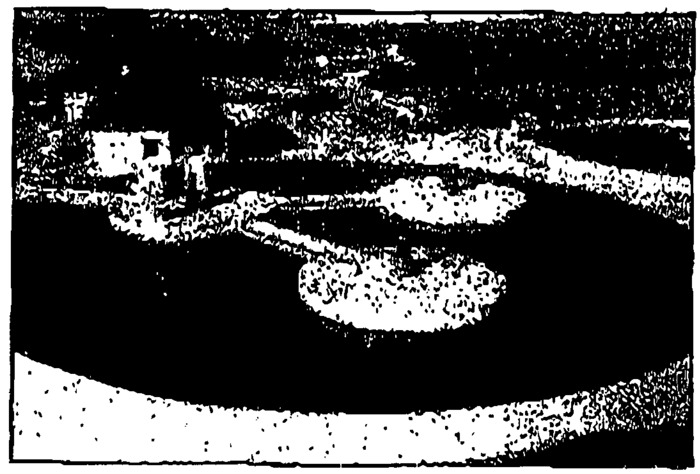
Highest Oxygen Transfer.

The proven TWISTER™ Low Speed Surface Aerator provides unmatched oxygen transfer rates, quality, and long lasting performance. These solidly built aerators use a partially submerged rotating turbine to effectively stir the basin while creating intense air-to-water mixing, resulting in high oxygen transfer. TWISTER™ Aerators feature:

* Strongly built gearbox with a safety factor of two or more
* Super resistant FRP rotor, uniquely shaped to maximize performance
* Fixed or float mounting

Typical TWISTER™ Low Speed Aerator on floats





Typical Twister Low Speed Aerator fixed mounted

Reduced Maintenance.

All shafts, couplings, gearbox's and support apparatus are oversized to reduce wear, vibration, and long term maintenance. The rotor is specially shaped and has proven to throw off debris and prevent ice build-up. It includes an adjustable base plate for level proper adjustment.

Extensive Applications.

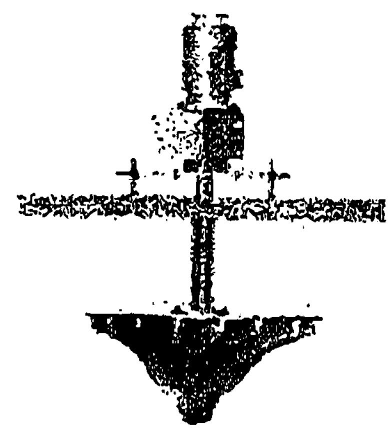
TWISTER™ Low Speed Surface Aerators add oxygen and mixing in a wide range of applications, including:

* Wastewater Treatment
* Leachate Treatment
* Supplemental Aeration
* Sequencing Batch Reactors

"Specialists in Aeration and Mixing Equipment"

Power Output HP / KW	3 / 2.2	5 / 4	7.5 / 5.5	10 / 7.5	15 / 10	20 / 15	25 / 18.5	30 / 22	40 / 30	50 / 37	60 / 45	75 / 55	100 / 75	125 / 90	150 / 110
Rotor rpm (60 or 50 Hz power)	73	97	110	133/60	70	75	77	61	70	70	70	<<<<<<<approximately 70>>>>>>>>			
Min. Basin Dia. (feet/meters)	16/5	16/5	23/7	23/7	30/9	34/10.5	34/10.5	39/12	39/12	39/12	49/15	49/15	50/18	60/21	79/24
Complete Mix Dia. (ft/mtrs)	33/10	43/13	48/15	59/18	68/20	76/23	79/24	85/26	93/28	102/31	108/33	118/36	131/40	144/44	167/48
Oxygen Dispersion Zone (ft/mtrs)	98/30	118/36	141/43	164/50	184/56	213/65	220/67	239/73	263/80	293/89	302/92	334/102	370/113	403/123	440/13[illegible]
Max Liquid Level Variation (in/cm)	3.1/8	3.1/6	3.1/8	3.1/8	3.9/10	3.9/10	3.9/10	3.9/10	3.9/10	3.9/10	3.9/10	3.9/10	7.9/20	7.9/20	7.9/20
Spray Diameter (feet/meters)	12/3.8	12/3.8	14/4.2	14/4.2	15/4.5	18/5.4	18/5.4	18/5.4	22/6.6	22/6.6	22/6.6	22/6.6	25/7.5	28/8.5	28/8.5
Minimum Liquid Level (ft/mtrs)	4.9/1.5	4.9/1.5	4.9/1.5	4.9/1.5	5.9/1.8	5.9/1.8	5.9/1.8	5.9/1.8	7.9/2.4	7.9/2.4	7.9/2.4	7.9/2.4	7.9/2.4	7.9/2.4	7.9/2.4
Oxygen Transfer - SAE motor	2.7 to 3.2 pounds per horsepower hour / 1.7 to 1.8 kgs per kw hour (all per ASCE)														
Approximate Weight (pounds)	396	440	528	618	1100	1650	2200	3000	3300	3520	3520	3960	5940	6600	8800
Approximate Weight (kgs)	180	200	240	280	500	750	1000	1400	1500	1600	1600	1800	2700	3000	4000

Notes:
All numbers are approximate.
Actual performance may vary.
All data subject to change.
Rotation speeds may vary 3 to 5 rpm depending on installation.



Aeration Knowledge. Wide Range Of Products.

AEROMIX is your aeration expert. We offer all major wastewater aeration technologies and the expertise to help you select and apply the equipment best suited for your application. Let our technical experts assist you in proper sizing, layout, and operation of your aeration system.

AEROMIX Systems, Inc.
2611 No. Second Street
Minneapolis, MN 55411 U.S.A.

Ph: 800/879-3677, 612/521-8519
Fax: 612/521-1455
e-mail: aeromix@aeromix.com
web site: www.aeromix.com

Rental units available.

```
Equipment Num        :: A-630
Eqipment Name        :: Recycled Water Tank Agitator
Associated PFD       :: PFD-P100-A601
Equipment Type       :: FIXED-PROP
Equipment Category   :: AGITATOR
Equipment Description:: 5 hp, 50 rpm,
Number Required      :: 1
Number Spares        :: 0
Scaling Stream       :: 602
Base Cost            :: 5963.00
Cost Basis           :: VENDOR
Cost Year            :: 1998
Base for Scaling     :: 179446.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 1.3000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.5100
Scale Factor Basis   :: GARRETT
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WT630
Utility Type         :: POWER
Date Modified        :: 12/10/98
Notes                :: Expected Power Req: 4 kW.
```

Eq. No.	A-630		
Eq. Name	Recycle Water Tank Agitator		
Associated PFD	A601		
Stream for Design	602		
Stream Description	Primary Inlet		
Flow Rate	179446	Kg/hr	R9809G
Average Density	0.999	g/CC	R9809G
Flowrate	790.7	gpm	
T-630 Calc. Tank	15813	gal	
Vendor Quote	$ 5,442		
	5	hp	
	13218	gal	Tank Volume for Agitator Quote
	0.92	hp/1000 ga	Back Calculated
Scaling Exponent	0.51		
Cost Estimate	**$ 5,963**	**1998**	
Scaling Stream	602		
Scaling Rate	179446		
Scaling Units	Kg/hr		

A-630 Water tank agitator

12' φ x 13' tall tank

1.3% insol. solids

4.9% Sol. Solids

91% H_2O

To Suspend solids

Jim Kassian
8-26-98

SVEDALA

Pumps & Process

SVEDALA PROPOSAL

SVEDALA Proposal No. 810306 Rev 0	**DATE PROCESSED: August 26, 1998 by Jim Puliafico**
Project: Merrick WWT Agitator	**Terms: Per Svedala Standard Terms & Conditions**

Svedala Pumps & Process Open-Agitator custom designed for use with a vertical cylindrical tank, 15 Ft diameter by 12 Ft straight-side high, with an open top and flat bottom. The mixer is designed to produce moderate agitation to suspend solids. The material agitated is a dilute slurry having a specific gravity of 1.03 and a viscosity of 3 cP. The slurry is made up of 3.5% by weight solids with a dry solids specific gravity of 2.8. The particle size distribution used is: d99=45, d80=15 and d50=8 microns.

The agitator is to be mounted on 15 inches high beams, mounted on tank centerline with full baffles. A square mounting plate is included to facilitate mounting of the agitator to the beams. The tank, baffles and agitator support structure are supplied by the customer.

The agitator consists of the following components:

- One propeller per shaft, 60 inch diameter, 4-blade MIL high efficiency propeller, bolted blade design, constructed of carbon steel. The prop will operate at a rotational speed of 50 rpm, resulting in a tip speed of 785 fpm. Prop is located31 in from tank floor to prop centerline.
- A 2.5 inch Schedule 80 pipe shaft constructed of carbon steel. A rigid coupling half is welded to the shaft for attachment to the reducer coupling half. For prop attachment, a hub plate is welded to the shaft. Shaft is approximately 126 inches long.
- Speed reducer, cycloidal gear, totally enclosed running in grease, Sumitomo Model No. CVVJS-4155-Y-35, ratio 35:1, with output shaft coupling half, C-Face mount motor adapter input and motor coupling.
- 5 HP motor, 1750 Rpm, 230/460V/3ph/60Hz, high efficiency, corrosive duty 184TC frame with drip cover.

Estimated weight each 520 Lbs

Unit Price: $5,442.00 FOB Colorado Springs, CO

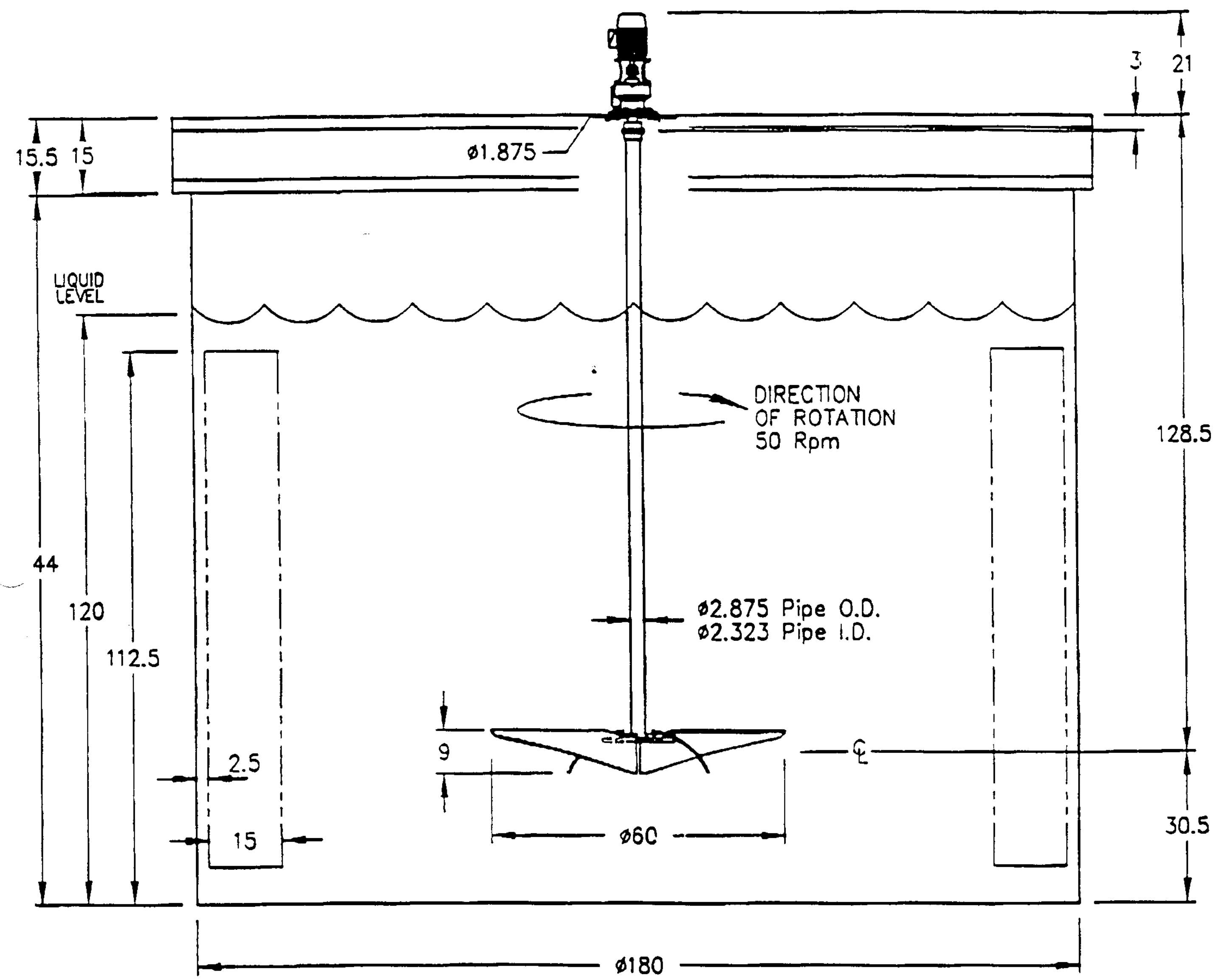
CUSTOMER			
	Customer: Merrick	PC#: 810306-1 Item#: 001	
	Agitator Tag Number :	Date: 26Aug98	
PROCESS			
	Service Description	: WWT Holding Tank	>
	Temperature & Pressure	: 100 <degF> & Atmospheric Pressure	>
	Final Mixture Viscosity	: 2.8	<cP @ 5s^-1>
	Sp. Gr. of Mixture	: 1.028	<g/cm3>
	Sp. Gr. of Liquid	: 1.000 (1 cP)	<g/cm3>
	Sp. Gr. of Dry Solids	: 2.800	<g/cm3>
	Weight % Solids	: 3.5	<%w/w>
	Solids Settling Vel. d99	: 0.50 Free 0.22 Hindered	<Fpm>
	Particle Size Distributn	: d99=45 d80=15 d50=7.5	<um>
TANK			
	Tank Diameter x Height	: 180 Diameter x 144 Str.Side	<inxin>
	Top / Bottom Geometry	: Flat / Flat	<in/in>
	Volume Agitated	: 13220 to 13220	<Gallons>
	Liquid Level Range	: 120 to 120	<in>
	Baffle Recommendation	: 4 @ 90 Deg. 15 Wide x 112.5 Long	<in>
	Tank Operation	: Continuous Flow w Bottom Draw-Off	>
AGITATOR			
	Agitator Model (Qty=1)	: Custom Agitator by Svedala Industries	>
	Agitator Shaft Seal	: No Shaft Seal is Used	>
	Mounting Type and Height	: On 15 in Beams with 1 in Bed-Plate	>
	No. of Impellers	: One (1) Single Impeller	< - >
	Impeller Style Used	: MIL	< - >
	Number of Blades	: 4 Bolted Blades	< - >
	Impeller Diameter	: 60	< in >
	D/T Ratio	: 0.333	< - >
	Operating Speed	: 50	<Rpm>
	Power Used By Turbines	: 1.7	< HP >
	Tip Speed	: 785	<Ft/min>
	Annular Velocity Vup	: 19.9	<Ft/min>
	Other Agitation Scales	: 1.56 Ft2/s2 3.54 Fpm/6 106 Turns/hr	>
	Total Impeller Pumping	: 23380	<gpm>
	Agitator Function	: Solid Suspension	>
SHAFT			
	Gear Box Shaft (Upper)	: 1.875 Dia.x 3.8 Long from Mtg.Ref.	<in>
	Pipe Shaft (Lower)	: 2.875/2.323D.(2.5 Sch80) x 126 Long	<in>
	Total Length / Coupling	: 128.7 Total / Removable/Pipe	<in/?>
	Turbine Dist to Mtg.Ref.	: 129	< in >
	Turbine Off-Bottom Dist.	: 31	< in >
	Weight of Impeller	: 174	<Lbs>
	Gear Box Shaft Stress	: Shear= 5835 Tensile= 9051	<psi>
	Pipe Shaft Stress	: Shear= 2796 Tensile= 4305	<psi>
	Hydraulic Safety Factor	: 3.00	< - >
DRIVE			
	Speed Reduction	: Sumitomo Cycloidal Gear w C-Face Motor	>
	Reducer Model	: CVVJS-4155-Y-35 Standard	>
	Gear Drive Ratio	: 35.000: 1 Single Reduction	< R:1 >
	Gearbox Service Factor	: 1.52	<HP/HP>
	Low Speed Bearing Life	: Upper= 78900 Lower= 599200	<B10 h/h>
MATERIALS			
	Impeller Matl/Cover	: C/S / No Cover	>
	Upper Shaft Material	: 4140 High Strength Steel	>
	Lower Shaft Matl/Cover	: C/S / No Cover	>
LOADS			
	DESIGN LOADS: (*)=APPROPRIATE SERVICE FACTOR APPLIED ALREADY		
	Bending Moment (* 1.8SF)	: 7455	<in-Lbf>
	Torque Moment (* 2.0SF)	: 12605	<in-Lbf>
	Downward Load (* 2.0SF)	: 1040	<Lbf>
	First Critical Speed	: 103.9 (0.48 Ratio)	<Rpm/(-)>
WEIGHTS			
	Weight of Agitator Drive	: 124	< Lbs >
	Weight of Motor	: 110	< Lbs >
	Weight of Wet-End	: 286	< Lbs >
	Total Weight of Agitator	: 520	< Lbs >
MOTOR			
	Motor Power / Rpm	: 5 / 1750 (230/460V/3/60Hz)	<HP/Rpm>
	Total Power Used	: 2.13 (43 % of Nameplate)	< HP >

DRAWN TO SCALE

DESIGN LOADS:

BENDING MOMENT:	7490	in–Lbf
TORQUE REACTION:	12610	in–Lbf
...NWARD LOAD:	990	Lbf
...CAL SPEED:	113	RPM

A... Loads Include An Appropriate Safety Factor



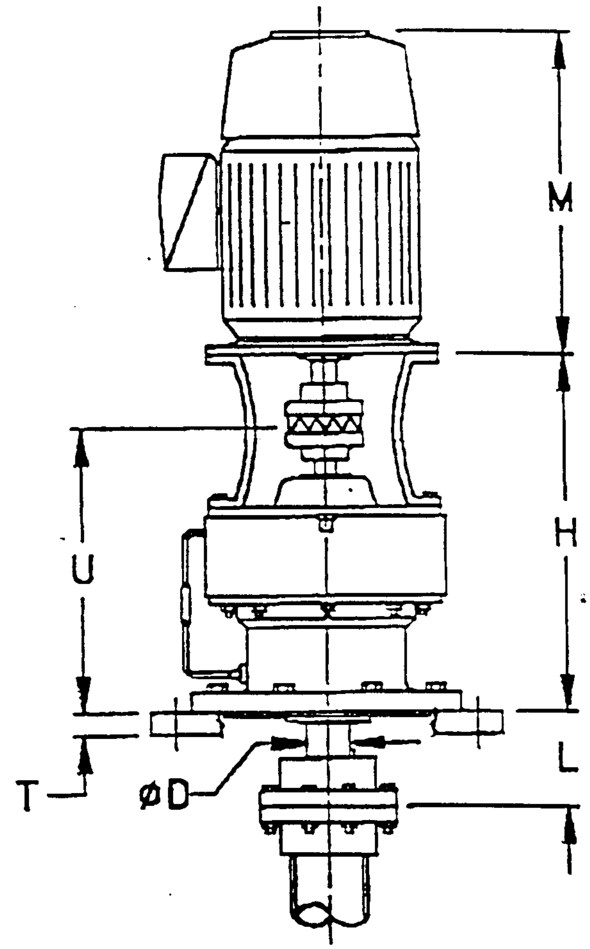
NOTE:

1. Dimensions in inches (in)
2. Motor: 5 HP at 1750 Rpm, Frame 184TC
3. V–Belt Drive: No Belts Are Used
4. Gear Reducer: Sumitomo CVVJS–4155–Y–35 Standard, Ratio 35:1, Gear S.F.=1.52, Cycloidal Gear, Grease Lubricated.
5. Seal: No Shaft Seal is Used
6. Shaft: One (1) Piece Extension Shaft 125.5 in Long, made from 2–1/2" Schedule 80 pipe.
7. Turbines: (1) ø60 in Diameter MIL Propeller with 4 Bolt–on Blades.
8. Process Slurry: 1.028 SpGr Mixture with 3.5%w/w Solids, 1.000 Liquid SpGr, 2.800 Solids SpGr, Maximum Particle Size 45 microns. No gas is added.
9. Wetted Parts: Carbon Steel

SVEDALA

Svedala Pumps & Process Industries
Agitators

LOCATION DRAWING
Merrick, Denver CO
WWT Holding Tank



MOTOR DATA

Power ____________

Rpm ____________

Frame ____________

Electricity ____________

SPEED REDUCER DATA

Mfgr ____________

Model ____________

Ratio ____________

Service Factor ____________

DIMENSIONS

M ____________

H ____________

L ____________

ØD ____________

T ____________

U ____________

N ____________

ØB ____________

ØQ ____________

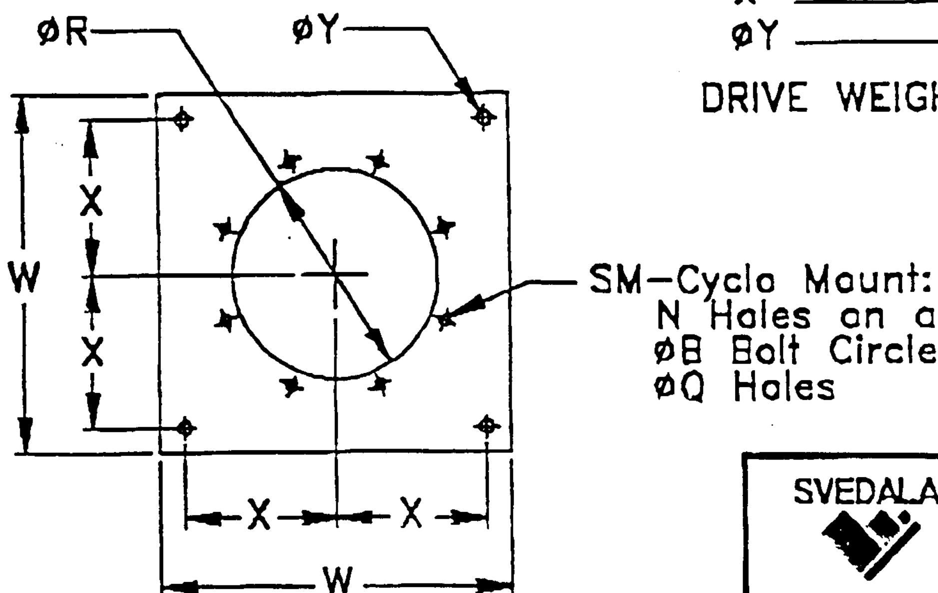
ØR ____________

W ____________

X ____________

ØY ____________

DRIVE WEIGHT: ____________



Optional Bed Plate.

SVEDALA	Svedala Pumps & Process Industries Agitators
SM–Cyclo Agitator Drive Motor Direct Connected Beam Mounted	
Rev.: Date:	Dwg. No.:

SM-Cyclo 4000 Series Features:

The smaller Svedala/Denver agitators often utilize the Sumitomo Cyclo speed reducer with the motor either directly connected or through a low ratio belt drive. A belt drive input to the reducer permits low cost speed flexibility should the process conditions change. The reducer service factor is based on the motor nameplate power rather than transmitted power. All SM-Cyclo speed used for agitator service are grease filled to guard against catastrophic lubrication oil loss through the lower bearing seals. The low speed B-10 bearing life are always calculated and are a minimum of 50,000 hours. Spare parts can be obtained directly from Sumitomo or through Svedala.

The SM-Cyclo is manufactured by Sumitomo Machinery who have had over 25 years of experience in building this unique speed reducers. Worldwide service is readily available through a network of regional offices and service technicians.

The SM-Cyclo reducer does not use any gears to achieve speed reduction; rather the design utilizes an eccentric cam, cycloidal discs, ring gear pins with rollers, and a low speed shaft with multiple roller pins. All torque transmitting parts roll with at least 2/3rds of the teeth engaged at any time. This contrasts with worm and bevel gearing which slide and helical and bevel gear teeth which have only a few teeth engaged at any time. As a result, no wear failures have every occurred with the Cyclo drive in over five million installations since 1939. Furthermore, the SM-Cyclo reducer can withstand over 500% shock load, the highest overload capacity of any speed reducer. The SM-Cyclo can quietly achieve 87:1 reduction in a single stage and still maintain 95% efficiency because all components roll. The transmission components are produced using 52100 high-carbon chromium bearing steel through-hardened and tempered to Rockwell C57 to C63. Using no gears, AGMA guidelines are meaningless.

Housings are manufactured from high-quality cast iron, built to withstand severe external loads. Grease filled reducers are specified by Svedala/Denver to ensure a long trouble-free life. Low speed shafts are manufactured from high alloy high strength steel (4140). Low speed shafts use either ball bearings of spherical roller bearings. Svedala/Denver works closely with the Sumitomo manufacturing to ensure the bearing life exceeds our minimum of 50,000 hours B-10 life with special attention given to the low speed bearings. In certain models, high capacity bearings are readily substituted for the standard bearings often resulting in a B-10 bearing life exceeded 100,000 hours.

```
Equipment Num        :: C-601
Eqipment Name        :: Lignin Wet Cake Screw
Associated PFD       :: PFD-P100-A601
Equipment Type       :: SCREW
Equipment Category   :: CONVEYOR
Equipment Description:: 14" DIA X 100' LONG
Number Required      :: 1
Number Spares        :: 0
Scaling Stream       :: 601
Base Cost            :: 31700.00
Cost Basis           :: ICARUS
Cost Year            :: 1997
Base for Scaling     :: 99199.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 1.4000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.7800
Scale Factor Basis   :: GARRETT
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WC601
Utility Type         :: POWER
Date Modified        :: 12/22/98
Notes                :: 85 hp (63 kW) specified by Icarus.
```

Eq. No.	C-601		
Eq. Name	Lignin Wet Cake Screw		
Associated PFD	A601		
Stream for Design	601		
Stream Description	Conveyor Inlet		
Flow Rate	99199	Kg/hr	R9809G
Average Density	0.99		
Frac Solids	0.303		
Density	61.8	lb/ft^3	
Flowrate	3532.7	cfh	Full Flow to Burner
Flow (tons/h)	109.1		
Design Basis	14	in. dia	Perry 5th, P. 7-7, Table 7-5, Max RPM, 45% Full
	4000	cfh	rated capacity
	100	ft. length	Assume its fairly close to the boiler
1/3 from Individual Separators	1178	cfh	per individual separator
	9	in. dia	Perry 5th, P. 7-7, Table 7-5, Max RPM, 45% Full
	1200	cfh	rated capacity
	15	ft. length	Assume its fairly close to the boiler
Cost Estimation			
Icarus 1997	**$ 21,900**	14" x 100'	1 unit
	$ 9,800	9" x 15'	2 units
	$ 31,700	Total	
Scaling Stream	601		
Scaling Rate	99199		
Scaling Units	Kg/hr		

C-601 CO - 100 C-601

COMPONENT DATA SHEET

SCREW

CODE OF ACCOUNT: 211

COMPONENT DESIGN DATA:

MATERIAL	CS
RATE	168.00 TPH
LENGTH	100.00 FEET
DIAMETER	14.00 INCHES
PROD DENSITY	50.00 PCF
DRIVER POWER	75.00 HP
TOTAL WEIGHT	8500 LBS

COST DATA:

ESTIMATED PURCHASE COST USD 21900.

	---MATERIAL---	*** M A N P O W E R ***		L/M RATIO
	USD	USD	MANHOURS	USD/USD
EQUIPMENT&SETTING	21900.	466.	25	0.021
PIPING	1354.	1314.	71	0.970
CIVIL	1976.	7142.	455	3.615
STRUCTURAL STEEL	988.	285.	17	0.288
INSTRUMENTATION	493.	0.	0	0.000
ELECTRICAL	506.	745.	38	1.472
INSULATION	0.	0.	0	0.000
PAINT	183.	416.	31	2.276
SUBTOTAL	27400.	10368.	637	0.378

INSTALLED DIRECT COST 37800. INST'L COST/PE RATIO 1.726

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:37:45

C-601short CO - 100 C-601short

COMPONENT DATA SHEET

SCREW

CODE OF ACCOUNT: 211

COMPONENT DESIGN DATA:

MATERIAL	A285C
RATE	69.00 TPH
LENGTH	15.00 FEET
DIAMETER	9.00 INCHES
PROD DENSITY	50.00 PCF
DRIVER POWER	5.00 HP
TOTAL WEIGHT	1100 LBS

COST DATA:

ESTIMATED PURCHASE COST USD 4900.

	MATERIAL	MANPOWER		L/M RATIO
	USD	USD	MANHOURS	USD/USD
EQUIPMENT&SETTING	4900.	466.	25	0.095
PIPING	897.	1058.	57	1.180
CIVIL	359.	1300.	83	3.619
STRUCTURAL STEEL	180.	52.	3	0.288
INSTRUMENTATION	493.	0.	0	0.000
ELECTRICAL	393.	668.	34	1.699
INSULATION	0.	0.	0	0.000
PAINT	90.	180.	13	1.995
SUBTOTAL	7312.	3724.	215	0.509

INSTALLED DIRECT COST 11000. INST'L COST/PE RATIO 2.245

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 17NOV98-14:10:54

```
Equipment Num        :: C-614
Eqipment Name        :: Aerobic Sludge Screw
Associated PFD       :: PFD-P100-A603
Equipment Type       :: SCREW
Equipment Category   :: CONVEYOR
Equipment Description:: 9" DIA X 25' LONG
Number Required      :: 1
Number Spares        :: 0
Scaling Stream       :: 623
Base Cost            :: 5700.00
Cost Basis           :: ICARUS
Cost Year            :: 1997
Base for Scaling     :: 978.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 1.4000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.7800
Scale Factor Basis   :: GARRETT
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WC614
Utility Type         :: POWER
Date Modified        :: 12/22/98
Notes                :: 7.5 hp (6 kW) specified by Icarus.
```

Eq. No.	C-614		
Eq. Name	Aerobic Sludge Screw		
Associated PFD	A603		
Stream for Design	623		
Stream Description	Conveyor Inlet		
Flow Rate	978	Kg/hr	R9809G
Average Density	1.12		
Frac Solids	0.252		
Density	69.9	lb/ft^3	
Flowrate	30.8	cfh	
Flow (tons/h)	1.1		
Design Basis	9	in. dia	Perry 5th, P. 7-7, Table 7-5, Max RPM, 30% Full
	280	cfh	rated capacity
	25	ft. length	Assume dumping into C601
Cost Estimation			
Icarus 1997			Attached
Scaling Stream	623		
Scaling Rate	978		
Scaling Units	Kg/hr		

C-614 CO - 100 C-614

COMPONENT DATA SHEET

SCREW

CODE OF ACCOUNT: 211

COMPONENT DESIGN DATA:

MATERIAL	CS
RATE	69.00 TPH
LENGTH	25.00 FEET
DIAMETER	9.00 INCHES
PROD DENSITY	50.00 PCF
DRIVER POWER	7.50 HP
TOTAL WEIGHT	1700 LBS

COST DATA:

ESTIMATED PURCHASE COST USD 5700.

	---MATERIAL---	*** M A N P O W E R ***		L/M RATIO
	USD	USD	MANHOURS	USD/USD
EQUIPMENT&SETTING	5700.	466.	25	0.082
PIPING	897.	1058.	57	1.180
CIVIL	539.	1950.	124	3.618
STRUCTURAL STEEL	269.	78.	5	0.288
INSTRUMENTATION	493.	0.	0	0.000
ELECTRICAL	393.	668.	34	1.699
INSULATION	0.	0.	0	0.000
PAINT	98.	203.	15	2.080
SUBTOTAL	8389.	4422.	260	0.527

INSTALLED DIRECT COST 12800. INST'L COST/PE RATIO 2.246

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:37:45

```
Equipment Num        :: H-602
Eqipment Name        :: Anaerobic Digestor Feed Cooler
Associated PFD       :: PFD-P100-A602
Equipment Type       :: SHELL-TUBE
Equipment Category   :: HEATX
Equipment Description:: TEMA BES TYPE, FLOATING HEAD
Number Required      :: 1
Number Spares        :: 0
Scaling Stream       :: AREA0602
Base Cost            :: 128600.00
Cost Basis           :: ICARUS
Cost Year            :: 1997
Base for Scaling     :: 7627.000
Base Type            :: SIZE
Base Units           :: SQF
Install. Factor      :: 2.1000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.7400
Scale Factor Basis   :: VENDOR
Material of Const    :: SS316
                        CS
Utility Calc.        :: ASPEN UOS BLOCK
Utility Stream       :: QH602
Utility Type         :: COOLING-WATER
Date Modified        :: 01/13/99
```

Eq. No.	H-602			
Eq. Name	Anerobic Digestor Feed Cooler			
Associated PFD	A602			
Stream for Design	QH602	7.3	MMKcal/hr	
	QH602	28.9	MMBtu/hr	Delta-T used 14.0 MMBtu/hr
Inlet	612	75	C	R9809G
Outlet	613	35	C	R9809G
Cooling Water Inlet	1046	28	C	
Cooling Water Outlet	1047	37	C	
LMTD		18.3	C	
LMTD		33.0	F	
U		115	BTU/(h*sf*	Merrick
Area total		7627	sf	

Cost Estimation				
LDR Quote 1	2,228 sf		$62,799	Merrick LDR Quote 9/1/98
LDR Quote 2	3,862 sf		$94,544	Merrick LDR Quote 9/1/98
Calc Scaling Exp	0.74			
Scaled Cost Total	$ 156,835		1998	SS 316

ICARUS- 1997	**$ 128,600**	**7,627**	**SQF**	**SS316 Tubes/CS Shell - Selected for Estimation**
	$ 153,200	7,627	SQF	SS316 Tubes/SS316 Shell - For Reference
	$ 72,500	2,228	SQF	SS316 Tubes/SS316 Shell - For Reference to above
	$ 217,500			3 @ 2228 sqft required - For Reference to above
	$ 106,100	3,862	SQF	SS316 Tubes/SS316 Shell - For Reference to above
	$ 212,200			2 @ 3862 sqft required - For Reference to above

Scaling Stream	AREA602
Scaling Rate	7627.0
Scaling Units	SQF

H-602 HE - 100 H-602

EQUIPMENT ITEM DESIGN DATA SHEET

FLOAT-HEAD

NO.	ITEM	VALUE SPECIFIED BY USER	VALUE USED BY SYSTEM	UNITS
GENERAL DESIGN DATA				
1.	TEMA TYPE		BES	
2.	SURFACE AREA	7627.0	7627.0	SF
3.	NUMBER OF SHELLS	1	1	
4.	NUMBER OF TUBE PASSES		2	
5.	NUMBER OF SHELL PASSES		1	
6.	VENDOR GRADE		HIGH	
SHELL DATA				
7.	SHELL MATERIAL SYMBOL	A 515	A 515	
8.	SHELL DIAMETER		44.00	INCHES
9.	SHELL LENGTH		33.00	FEET
10.	SHELL PRESSURE		150.0	PSIG
11.	SHELL TEMPERATURE		650.0	DEG F
12.	CORROSION ALLOWANCE		0.1250	INCHES
13.	SHELL THICKNESS		0.4375	INCHES
14.	ASA RATING		300	
15.	NUMBER OF BAFFLES		22	
16.	SHELL FABRICATION TYPE		PLATE	
17.	EXPANSION JOINT		NO	
TUBE DATA				
18.	TUBE MATERIAL SYMBOL	316LW	316LW	
19.	NUMBER OF TUBES		972	
20.	TUBE DIAMETER (OD)		1.000	INCHES
21.	TUBE LENGTH		30.00	FEET
22.	TUBE PRESSURE		150.0	PSIG
23.	TUBE TEMPERATURE		650.0	DEG F
24.	TUBE CORROSION ALLOWANCE		0.0000	INCHES
25.	TUBE WALL THICKNESS		0.0490	INCHES
26.	TUBE GAGE		18	BWG
27.	PITCH TYPE		TRIANGULAR	
28.	TUBE PITCH		1.250	INCHES
29.	TUBE SEAL TYPE		SEALW	
TUBE SHEET DATA				
30.	TUBE SHEET MATERIAL		316L	
31.	TUBE SHEET THICKNESS		2.750	INCHES
32.	CORROSION ALLOWANCE		0.0000	INCHES
33.	CHANNEL MATERIAL SYMBOL		316L	
FLOATING HEAD DATA				
34.	HEAD MATERIAL SYMBOL		316L	
35.	FLOATING HEAD THICKNESS		0.3750	INCHES
SHELL SIDE HEAD DATA				
36.	HEAD MATERIAL SYMBOL		A 515	
37.	ASA RATING		300	
38.	HEAD THICKNESS		0.4375	INCHES
HEAD DATA				
39.	HEAD MATERIAL SYMBOL		316L	
40.	ASA RATING		300	
41.	HEAD THICKNESS		0.3750	INCHES
WEIGHT DATA				
42.	SHELL		6900	LBS
43.	TUBES		14800	LBS
44.	HEADS		1300	LBS
45.	INTERNALS/BAFFLES		3000	LBS
46.	NOZZLES		870	LBS

47.	FLANGES	4300	LBS
48.	BASE RING + LUGS	60	LBS
49.	TUBE SHEET	1500	LBS
50.	SADDLES	340	LBS
51.	FITTINGS, ETC.	2600	LBS
52.	TOTAL WEIGHT	35700	LBS

VENDOR COST DATA

53.	MATERIAL COMPONENT COST	77073	USD
54.	SHOP MANPOWER COST	15882	USD
55.	SHOP OVERHEAD	15861	USD
56.	GENERAL OFFICE OVERHEAD	9598	USD
57.	PROFIT	10186	USD
58.	TOTAL COST	128600	USD
59.	RESULTING UNIT COST	3.602	USD/LBS
60.	RESULTING UNIT COST	16.86	USD/SF

	MATERIAL	M A N P O W E R		L/M RATIO
	USD	USD	MANHOURS	USD/USD
EQUIPMENT&SETTING	128600.	870.	47	0.007
PIPING	99708.	16445.	890	0.165
CIVIL	1062.	1442.	92	1.358
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	10467.	2457.	127	0.235
ELECTRICAL	0.	0.	0	0.000
INSULATION	21940.	9824.	559	0.448
PAINT	225.	457.	33	2.031
SUBTOTAL	262001.	31494.	1748	0.120

INSTALLED DIRECT COST 293500. INST'L COST/PE RATIO 2.282

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 13JAN99-13:31:50

H-602 HE - 100 H-602

EQUIPMENT ITEM DESIGN DATA SHEET

FLOAT-HEAD

NO.	ITEM	VALUE SPECIFIED BY USER	VALUE USED BY SYSTEM	UNITS
	GENERAL DESIGN DATA			
1.	TEMA TYPE		BES	
2.	SURFACE AREA	7627.0	7627.0	SF
3.	NUMBER OF SHELLS	1	1	
4.	NUMBER OF TUBE PASSES		2	
5.	NUMBER OF SHELL PASSES		1	
6.	VENDOR GRADE		HIGH	
	SHELL DATA			
7.	SHELL MATERIAL SYMBOL	SS316	SS316	
8.	SHELL DIAMETER		44.00	INCHES
9.	SHELL LENGTH		33.00	FEET
10.	SHELL PRESSURE		150.0	PSIG
11.	SHELL TEMPERATURE		650.0	DEG F
12.	CORROSION ALLOWANCE		0.0000	INCHES
13.	SHELL THICKNESS		0.4375	INCHES
14.	ASA RATING		300	
15.	NUMBER OF BAFFLES		22	
16.	SHELL FABRICATION TYPE		PLATE	
17.	EXPANSION JOINT		NO	
	TUBE DATA			
18.	TUBE MATERIAL SYMBOL	316LW	316LW	
19.	NUMBER OF TUBES		972	
20.	TUBE DIAMETER (OD)		1.000	INCHES
21.	TUBE LENGTH		30.00	FEET
22.	TUBE PRESSURE		150.0	PSIG
23.	TUBE TEMPERATURE		650.0	DEG F
24.	TUBE CORROSION ALLOWANCE		0.0000	INCHES
25.	TUBE WALL THICKNESS		0.0490	INCHES
26.	TUBE GAGE		18	BWG
27.	PITCH TYPE		TRIANGULAR	
28.	TUBE PITCH		1.250	INCHES
29.	TUBE SEAL TYPE		SEALW	
	TUBE SHEET DATA			
30.	TUBE SHEET MATERIAL		316L	
31.	TUBE SHEET THICKNESS		2.750	INCHES
32.	CORROSION ALLOWANCE		0.0000	INCHES
33.	CHANNEL MATERIAL SYMBOL		316L	
	FLOATING HEAD DATA			
34.	HEAD MATERIAL SYMBOL		316L	
35.	FLOATING HEAD THICKNESS		0.3750	INCHES
	SHELL SIDE HEAD DATA			
36.	HEAD MATERIAL SYMBOL		SS316	
37.	ASA RATING		300	
38.	HEAD THICKNESS		0.4375	INCHES
	HEAD DATA			
39.	HEAD MATERIAL SYMBOL		316L	
40.	ASA RATING		300	
41.	HEAD THICKNESS		0.3750	INCHES
	WEIGHT DATA			
42.	SHELL		7000	LBS
43.	TUBES		14800	LBS
44.	HEADS		1300	LBS
45.	INTERNALS/BAFFLES		3000	LBS
46.	NOZZLES		870	LBS

47.	FLANGES	4400	LBS
48.	BASE RING + LUGS	60	LBS
49.	TUBE SHEET	1500	LBS
50.	SADDLES	340	LBS
51.	FITTINGS, ETC.	2700	LBS
52.	TOTAL WEIGHT	36000	LBS

VENDOR COST DATA

53.	MATERIAL COMPONENT COST	94324	USD
54.	SHOP MANPOWER COST	17758	USD
55.	SHOP OVERHEAD	17484	USD
56.	GENERAL OFFICE OVERHEAD	11446	USD
57.	PROFIT	12188	USD
58.	TOTAL COST	153200	USD
59.	RESULTING UNIT COST	4.256	USD/LBS
60.	RESULTING UNIT COST	20.09	USD/SF

	---MATERIAL---	*** M A N P O W E R ***		L/M RATIO
	USD	USD	MANHOURS	USD/USD
EQUIPMENT&SETTING	153200.	870.	47	0.006
PIPING	120746.	18691.	1012	0.155
CIVIL	1062.	1442.	92	1.358
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	10862.	2457.	127	0.226
ELECTRICAL	0.	0.	0	0.000
INSULATION	21940.	9824.	559	0.448
PAINT	0.	0.	0	0.000
SUBTOTAL	307809.	33284.	1837	0.108

INSTALLED DIRECT COST 341100. INST'L COST/PE RATIO 2.227

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 13JAN99-13:31:50

H-602 HE - 100 H-602

EQUIPMENT ITEM DESIGN DATA SHEET

FLOAT-HEAD

NO.	ITEM	VALUE SPECIFIED BY USER	VALUE USED BY SYSTEM	UNITS
	GENERAL DESIGN DATA			
1.	TEMA TYPE		BES	
2.	SURFACE AREA	3862.0	3862.0	SF
3.	NUMBER OF SHELLS		1	
4.	NUMBER OF TUBE PASSES		2	
5.	NUMBER OF SHELL PASSES		1	
6.	VENDOR GRADE		HIGH	
	SHELL DATA			
7.	SHELL MATERIAL SYMBOL	SS316	SS316	
8.	SHELL DIAMETER		38.00	INCHES
9.	SHELL LENGTH		23.00	FEET
10.	SHELL PRESSURE		150.0	PSIG
11.	SHELL TEMPERATURE		650.0	DEG F
12.	CORROSION ALLOWANCE		0.0000	INCHES
13.	SHELL THICKNESS		0.4375	INCHES
14.	ASA RATING		300	
15.	NUMBER OF BAFFLES		18	
16.	SHELL FABRICATION TYPE		PLATE	
17.	EXPANSION JOINT		NO	
	TUBE DATA			
18.	TUBE MATERIAL SYMBOL	316LW	316LW	
19.	NUMBER OF TUBES		738	
20.	TUBE DIAMETER (OD)		1.000	INCHES
21.	TUBE LENGTH		20.00	FEET
22.	TUBE PRESSURE		150.0	PSIG
23.	TUBE TEMPERATURE		650.0	DEG F
24.	TUBE CORROSION ALLOWANCE		0.0000	INCHES
25.	TUBE WALL THICKNESS		0.0490	INCHES
26.	TUBE GAGE		18	BWG
27.	PITCH TYPE		TRIANGULAR	
28.	TUBE PITCH		1.250	INCHES
29.	TUBE SEAL TYPE		SEALW	
	TUBE SHEET DATA			
30.	TUBE SHEET MATERIAL		316L	
31.	TUBE SHEET THICKNESS		2.500	INCHES
32.	CORROSION ALLOWANCE		0.0000	INCHES
33.	CHANNEL MATERIAL SYMBOL		316L	
	FLOATING HEAD DATA			
34.	HEAD MATERIAL SYMBOL		316L	
35.	FLOATING HEAD THICKNESS		0.3125	INCHES
	SHELL SIDE HEAD DATA			
36.	HEAD MATERIAL SYMBOL		SS316	
37.	ASA RATING		300	
38.	HEAD THICKNESS		0.4375	INCHES
	HEAD DATA			
39.	HEAD MATERIAL SYMBOL		316L	
40.	ASA RATING		300	
41.	HEAD THICKNESS		0.3125	INCHES

WEIGHT DATA

42.	SHELL	4200	LBS
43.	TUBES	7500	LBS
44.	HEADS	930	LBS
45.	INTERNALS/BAFFLES	1900	LBS
46.	NOZZLES	690	LBS
47.	FLANGES	3400	LBS
48.	BASE RING + LUGS	36	LBS
49.	TUBE SHEET	1000	LBS
50.	SADDLES	270	LBS
51.	FITTINGS, ETC.	1800	LBS
52.	TOTAL WEIGHT	21700	LBS

VENDOR COST DATA

53.	MATERIAL COMPONENT COST	60120	USD
54.	SHOP MANPOWER COST	14259	USD
55.	SHOP OVERHEAD	14027	USD
56.	GENERAL OFFICE OVERHEAD	8506	USD
57.	PROFIT	9188	USD
58.	TOTAL COST	106100	USD
59.	RESULTING UNIT COST	4.889	USD/LBS
60.	RESULTING UNIT COST	27.47	USD/SF

	MATERIAL	M A N P O W E R		L/M RATIO
	USD	USD	MANHOURS	USD/USD
EQUIPMENT&SETTING	106100.	752.	41	0.007
PIPING	80938.	14457.	782	0.179
CIVIL	938.	1321.	84	1.408
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	9574.	2411.	125	0.252
ELECTRICAL	0.	0.	0	0.000
INSULATION	17717.	7699.	438	0.435
PAINT	0.	0.	0	0.000
SUBTOTAL	215268.	26640.	1470	0.124

INSTALLED DIRECT COST 241900. INST'L COST/PE RATIO 2.280

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:45:13

H-602 HE - 100 H-602

EQUIPMENT ITEM DESIGN DATA SHEET

FLOAT-HEAD

NO.	ITEM	VALUE SPECIFIED BY USER	VALUE USED BY SYSTEM	UNITS
	GENERAL DESIGN DATA			
1.	TEMA TYPE		BES	
2.	SURFACE AREA	2228.0	2228.0	SF
3.	NUMBER OF SHELLS		1	
4.	NUMBER OF TUBE PASSES		2	
5.	NUMBER OF SHELL PASSES		1	
6.	VENDOR GRADE		HIGH	
	SHELL DATA			
7.	SHELL MATERIAL SYMBOL	SS316	SS316	
8.	SHELL DIAMETER		30.00	INCHES
9.	SHELL LENGTH		23.00	FEET
10.	SHELL PRESSURE		150.0	PSIG
11.	SHELL TEMPERATURE		650.0	DEG F
12.	CORROSION ALLOWANCE		0.0000	INCHES
13.	SHELL THICKNESS		0.4375	INCHES
14.	ASA RATING		300	
15.	NUMBER OF BAFFLES		18	
16.	SHELL FABRICATION TYPE		PLATE	
17.	EXPANSION JOINT		NO	
	TUBE DATA			
18.	TUBE MATERIAL SYMBOL	316LW	316LW	
19.	NUMBER OF TUBES		426	
20.	TUBE DIAMETER (OD)		1.000	INCHES
21.	TUBE LENGTH		20.00	FEET
22.	TUBE PRESSURE		150.0	PSIG
23.	TUBE TEMPERATURE		650.0	DEG F
24.	TUBE CORROSION ALLOWANCE		0.0000	INCHES
25.	TUBE WALL THICKNESS		0.0490	INCHES
26.	TUBE GAGE		18	BWG
27.	PITCH TYPE		TRIANGULAR	
28.	TUBE PITCH		1.250	INCHES
29.	TUBE SEAL TYPE		SEALW	
	TUBE SHEET DATA			
30.	TUBE SHEET MATERIAL		316L	
31.	TUBE SHEET THICKNESS		1.875	INCHES
32.	CORROSION ALLOWANCE		0.0000	INCHES
33.	CHANNEL MATERIAL SYMBOL		316L	
	FLOATING HEAD DATA			
34.	HEAD MATERIAL SYMBOL		316L	
35.	FLOATING HEAD THICKNESS		0.2500	INCHES
	SHELL SIDE HEAD DATA			
36.	HEAD MATERIAL SYMBOL		SS316	
37.	ASA RATING		300	
38.	HEAD THICKNESS		0.4375	INCHES
	HEAD DATA			
39.	HEAD MATERIAL SYMBOL		316L	
40.	ASA RATING		300	
41.	HEAD THICKNESS		0.2500	INCHES

WEIGHT DATA

42.	SHELL	3300	LBS
43.	TUBES	4300	LBS
44.	HEADS	560	LBS
45.	INTERNALS/BAFFLES	1100	LBS
46.	NOZZLES	400	LBS
47.	FLANGES	2200	LBS
48.	BASE RING + LUGS	29	LBS
49.	TUBE SHEET	540	LBS
50.	SADDLES	180	LBS
51.	FITTINGS, ETC.	1300	LBS
52.	TOTAL WEIGHT	13900	LBS

VENDOR COST DATA

53.	MATERIAL COMPONENT COST	39141	USD
54.	SHOP MANPOWER COST	10552	USD
55.	SHOP OVERHEAD	10042	USD
56.	GENERAL OFFICE OVERHEAD	6095	USD
57.	PROFIT	6670	USD
58.	TOTAL COST	72500	USD
59.	RESULTING UNIT COST	5.216	USD/LBS
60.	RESULTING UNIT COST	32.54	USD/SF

	MATERIAL	M A N P O W E R		L/M RATIO
	USD	USD	MANHOURS	USD/USD
EQUIPMENT&SETTING	72500.	752.	41	0.010
PIPING	52945.	11775.	637	0.222
CIVIL	783.	1163.	74	1.485
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	10723.	2411.	125	0.225
ELECTRICAL	0.	0.	0	0.000
INSULATION	14357.	6666.	379	0.464
PAINT	0.	0.	0	0.000
SUBTOTAL	151308.	22767.	1256	0.150

INSTALLED DIRECT COST 174100. INST'L COST/PE RATIO 2.401

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:45:13

LDR CORP.

100 S. ADAMS RD
SAND SPRINGS OK. 74063
TELE: 918-241-0174
FAX: 918-241-0175

TO: MERRICK ENGINEERS
P.O. BOX 22026
DENVER, CO 80222
ATTN: CHRISTY SCHMID

QUOTE #	98-642
DATE	9/1/98
INQUIRY DATE	8/26/98
INQUIRY #	19013104
* EST DELIVERY	12 WEEKS
** TERMS	PROGRESS PAYMENTS
F.O.B	SAND SPRINGS. OK
SHIPPED V.I.A.	TRUCK
SALESMAN	G. LAWHORN/FRY

QTY	DESCRIPTION	PRICE EACH	AMOUNT
	MATERIAL, LABOR AND ENGINEERING TO FABRICATE:		
	"BUDGET PRICES ONLY"		
ONE	27 X 288 TEMA TYPE B E S HEAT EXCHANGER PER ATTACHED LDR SPECIFICATION SHEET. TAG: ITEM NO. H-602 ESTIMATED WEIGHT: 11,700 LBS. ALL MATERIAL: 316 STAINLESS STEEL 473 TUBES: 0.75" O.D. X .065(AVG) BWG X 24' LG; SA-249-TP316 STAINLESS STEEL PRICE:		62,799.0
	35 X 288 TEMA TYPE B E S HEAT EXCHANGER PER ATTACHED LDR SPECIFICATION SHEET. TAG: ITEM NO. H-602 ALT. ESTIMATED WEIGHT: 18,400 LBS. ALL MATERIAL: 316 STAINLESS STEEL 820 TUBES: 0.75" O.D. X .065(AVG) BWG X 24' LG; SA-249-TP316 STAINLESS STEEL PRICE:		94,544.0
ONE	26 X 288 TEMA TYPE B E S HEAT EXCHANGER PER ATTACHED LDR SPECIFICATION SHEET. TAG: ITEM NO. H-606 ESTIMATED WEIGHT: 10,700 LBS. ALL MATERIAL: 316 STAINLESS STEEL 418 TUBES: 0.75" O.D. X .065(AVG) BWG X 24' LG; SA-249-TP316 STAINLESS STEEL PRICE:		57,969.0
	** PROGRESS PAYMENTS REQUIRED: 10% UPON DRAWING APPROVAL SUBMITTAL 30% UPON RECEIPT OF MATERIALS LESS TUBES 20% UPON RECEIPT OF TUBES BALANCE UPON COMPLETION		
	* DELIVERY AS QUOTED IS AFTER RECEIPT OF APPROVAL DRAWINGS. PRICES ARE BASED ON USING FCAW WELDING.		

BY:

FIGURE G-5.2
HEAT EXCHANGER SPECIFICATION SHEET

		Job No.	
Customer	MERRICK	Reference No.	
Address		Proposal No.	
Plant Location		Date	Rev.
Service of Unit	ANAEROBIC DIGESTOR FEED Cooler	Item No.	H-602
Size	27-288 Type (Hor/~~Vert~~) BES	Connected In	~~Parallel~~ ~~Series~~
Surf/Unit (~~Gross~~/Eff.)	2181 Sq Ft; Shells/Unit 1	Surf/Shell (Gross/Eff.)	2181 Sq Ft

PERFORMANCE OF ONE UNIT

Fluid Allocation	Shell Side		Tube Side	
Fluid Name	DIGESTOR FEED		C WATER	
Fluid Quantity, Total Lb/Hr	160110 X 1.15		1162332 X 1.15	
Vapor (In/Out)				
Liquid	160110X1.15		1162332X1.15	
Steam				
Water				
Noncondensable				
Temperature (In/Out) °F	248	131	82.4	98.6
Specific Gravity	120°C	55°C	27	37
Viscosity, Liquid Cp				
Molecular Weight, Vapor				
Molecular Weight, Noncondensable				
Specific Heat Btu/Lb °F				
Thermal Conductivity Btu Ft/Hr Sq Ft °F				
Latent Heat Btu/Lb @ °F				
Inlet Pressure Psig				
Velocity Ft/S				
Pressure Drop, Allow./Calc. Psi	5 / 5		5 / 5	
Fouling Resistance (Min.)	.002		.002	

Heat Exchanged 18830000 X 1.15 Btu/Hr; MTD (Corrected) 86 °F

Transfer Rate, Service 115.45 Clean Btu/Hr Sq Ft °F

CONSTRUCTION OF ONE SHELL — Sketch (Bundle/Nozzle Orientation)

	Shell Side	Tube Side
Design/Test Pressure Psig	75 /	150 /
Design Temperature °F	300	300
No. Passes per Shell	1	1 X
Corrosion Allowance In.	0	0
Connections Size & Rating — In	6	16
Out	6	16
Intermediate		

Tube No. 473 OD 3/4 In.; Thk (Min/Avg) 16 In.; Length 24 Ft; Pitch 1" SQ In. ⟶ 30 ⟶ 60 ⟶ 90 ⟶ 45

Tube Type	316SS	Material	
Shell	316SS ID 27 ~~OD~~ In.	Shell Cover	316SS (Integ.) (Remov.)
Channel or Bonnet	316SS	Channel Cover	316SS
Tubesheet-Stationary	316SS	Tubesheet-Floating	316SS
Floating Head Cover	316SS	Impingement Protection	yes
Baffles-Cross	316SS Type SEGM	% Cut (Diam/Area)	Spacing: c/c Inlet In.
Baffles-Long		Seal Type	
Supports-Tube	U-Bend	Type	
Bypass Seal Arrangement		Tube-Tubesheet Joint	
Expansion Joint	316SS	Type	X BELLOWS OR PACKING GLAND.
ρv²-Inlet Nozzle	Bundle Entrance	Bundle Exit	
Gaskets-Shell Side		Tube Side	
-Floating Head			
Code Requirements		TEMA Class	
Weight/Shell	Filled with Water	Bundle	Lb
Remarks			

472 tubes +24 x 1.9635 = 2222

MERRICK®
Engineers & Architects

HEAT EXCHANGER

DATE 8/25/98 SHEET 1 OF 1
DATA SHEET #
BY CPS CHK'D

CLIENT
PROJECT
LOCATION
CONTRACT # / TASK 19013104

REVISION	DATE	BY

SIZE: TYPE: SURFACE AREA: FT²
EQUIPMENT NO./DESCRIPTION H-602, ANAEROBIC DIGESTOR FEED COOLER DRAWING NO.
LOCATION:

CONDITIONS OF SERVICE (ONE UNIT)

HEAT EXCHANGED 4.745 MM KCAL/HR | MTD(WTD)(CORR) °C | TRANSFER RATE: SERVICE | CLEAN

	SHELL SIDE		TUBE SIDE	
FLUID CIRCULATED	DIGESTER FEED		COOLING WATER	
TOTAL FLUID ENTERING	72,626 KG/HR		527,222 KG/HR	
	IN	OUT	IN	OUT
VAPOR KG/HR (MWT)	0	0		
LIQUID KG/HR	72,626	72,626		
STEAM KG/HR				
WATER KG/HR			527,222	527,222
NONCONDENSABLES KG/HR (MWT)				
LIQUID GRAVITY @ TEMP.		0.966		
VISCOSITY: LIQUID, CP				
HEAT: LATENT, BTU/LB; SP; BTU/LB DEG F				
THERM COND:BTU/(HR)(SQ FT)(DEG F PER FT)				
TEMPERATURE °C	120	55	28	37
OPERATING PRESSURE ATM	2.03	2.03	4.14	4.14
VELOCITY				
NO. PASSES				
PRESSURE DROP ATM	ALLOW.	CALC.	ALLOW.	CALC.
FOULING RESISTANCE (MIN.)				

CONSTRUCTION

PRESSURE, ATM	DESIGN	TEST	DESIGN	TEST
DESIGN TEMPERATURE, °C				

NO. TUBES | O.D. IN. | MIN AVG.
LENGTH FT. | PITCH IN
SHELL DIAM IN. ID IN. OD | MAX. BUNDLE DIAM ALLOW
TRANS BAFFLE | SPACING IN OUT %
LONG BAFFLE | INPINGMENT BAFFL YES NO

	SHELL SIDE NO.	SHELL SIDE SIZE	SHELL SIDE RATING & FACING	TUBE SIDE NO.	TUBE SIDE SIZE	TUBE SIDE RATING & FACING
INLET	1	10"		1	16"	
OUTLET	1	6"		1	16"	
VENT						
DRAIN						
TEMP CONN						
PRESS CONN						

MATERIALS: (MARK SR & XR - S=SPOT, F=FULL)

ITEM	MATERIAL SPECIFICATION	XR & SR
TUBES	316 SS	
SHELL	316 SS	
SHELL COVER(REM)(INTEG)		
CHANNEL	316 SS	
CHAN. COVER(REM)(INTEG)		
FLOATING-HEAT COVER		
TUBE SHEETS		
BAFFLES & SUPPORT PLATES		
BOLTING: SHELL COVER		
CHANNEL & COVER		
FLOATING HEAD		

SLIP-ON NOZZLE FLANGES ALLOWED YES NO
SLIP-ON ENG FLANGES ALLOWED YES NO
CORROSION ALLOW. | SHELL SIDE IN. | TUBE SIDE IN.
GASKETS: SHELL
CHANNEL
FLOATING-HEAD COVER
TEST RINGS | SPAR GASKETS
STACKING HIGH
WEIR HEIGHT | VOLUME BEHIND WEIR

TEMA CLASS: | CODE REQUIREMENTS AND SPECS:
WEIGHTS PER SHELL | SHIPPING LB. | FULL OF WATER LB. | BUNDLE LB.

REMARKS: DIGESTER FEED CONTAINS APPROX. 1% SOLIDS AND IS 96% WATER
INCLUDE 15% EXCESS AREA AND FLOW, ALL WETTED PARTS TO BE 316 SS

FIGURE G-5.2
HEAT EXCHANGER SPECIFICATION SHEET

1			Job No.	
2	Customer	MERRICK	Reference No.	
3	Address		Proposal No.	
4	Plant Location		Date	Rev.
5	Service of Unit	H-606 ANAEROBIC DIGESTOR FEED Cooler	Item No.	H-602 A&B
6	Size 35-288	Type (Hor/~~Vert~~) BES	Connected In	Parallel Series
7	Surf/Unit (~~Gross~~/Eff.) 3781 Sq Ft	Shells/Unit 1	Surf/Shell (~~Gross~~/Eff.) 3781	Sq Ft
8	PERFORMANCE OF ONE UNIT			
9	Fluid Allocation		Shell Side	Tube Side
10	Fluid Name		DIGESTER FEED	C. WATER
11	Fluid Quantity, Total	Lb/Hr	160111 x 1.15	2793228 x 1.15
12	Vapor (In/Out)		28820x1.15 / —	
13	Liquid		/ 160111x1.15	2793228 x 1.15
14	Steam			
15	Water			
16	Noncondensable			
17	Temperature (In/Out)	°F	248 (D.P.) / 131	
18	Specific Gravity			
19	Viscosity, Liquid	Cp		
20	Molecular Weight, Vapor		18.	
21	Molecular Weight, Noncondensable			
22	Specific Heat	Btu/Lb °F		
23	Thermal Conductivity	Btu Ft/Hr Sq Ft °F		
24	Latent Heat	Btu/Lb @ °F	946	
25	Inlet Pressure	Psig		
26	Velocity	Ft/S		
27	Pressure Drop, Allow./Calc.	Psi	5 / 5	5 / 7
28	Fouling Resistance (Min.)		.002	.002
29	Heat Exchanged 45597000 x 1.15	Btu/Hr;	MTD (Corrected)	110.2 WTD °F
30	Transfer Rate, Service	126.9	Clean	Btu/Hr Sq Ft °F
31	CONSTRUCTION OF ONE SHELL			Sketch (Bundle/Nozzle Orientation)
32		Shell Side	Tube Side	
33	Design/Test Pressure Psig	75 /	150 /	
34	Design Temperature °F	300	300	
35	No. Passes per Shell	1	1 *	
36	Corrosion Allowance In.	0	0	
37	Connections Size & Rating — In	10	24	
38	Out	6	24	
39	Intermediate			
40	Tube No. 820 OD 3/4 In.; Thk (Min/Avg) 16 In.; Length 24 Ft; Pitch 15/16 In.			◁ 30 △ 60 ◇ 90 ◇ 45
41	Tube Type 316SS Bare		Material	
42	Shell 316SS 35 ID ~~OD~~ In.		Shell Cover 316SS	(Integ.) (Remov.)
43	Channel or Bonnet 316SS		Channel Cover 316SS	
44	Tubesheet-Stationary 316SS		Tubesheet-Floating 316SS	
45	Floating Head Cover 316SS		Impingement Protection yes	
46	Baffles-Cross 316SS Type SEGM		% Cut (Diam/Area)	Spacing: c/c Inlet In.
47	Baffles-Long		Seal Type	
48	Supports-Tube	U-Bend		Type
49	Bypass Seal Arrangement		Tube-Tubesheet Joint	
50	Expansion Joint 316SS		Type * BELLOWS OR PACKING GLAND.	
51	ρv^2-Inlet Nozzle	Bundle Entrance		Bundle Exit
52	Gaskets-Shell Side		Tube Side	
53	-Floating Head			
54	Code Requirements			TEMA Class
55	Weight/Shell	Filled with Water		Bundle Lb
56	Remarks			
57				
58				
59				
60				
61				

```
Equipment Num        :: M-604
Eqipment Name        :: Nutrient Feed System
Associated PFD       :: PFD-P100-A602
Equipment Type       :: PACKAGE
Equipment Category   :: MISCELLANEOUS
Equipment Description:: 5 TANKS AND PUMPS
Number Required      :: 1
Number Spares        :: 0
Base Cost            :: 31400.00
Cost Basis           :: VENDOR
Cost Year            :: 1998
Install. Factor      :: 2.5800
Install. Factor Basis:: VENDOR
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WM604
Utility Type         :: POWER
Date Modified        :: 01/13/99
Notes                :: Expected Power Req: 8 kW. Small system that
                        doesn't require scaling for other cases.
```

Eq. No.	M-604		
Eq. Name	Nutrient Feed System		
Associated PFD	A602		
Stream for Design	N/A		No Scaling
Power Requirement	10	hp	Estimated
Cost Estimation	Purchase	Installation	
			Phoenix Bio-Systems, Inc. Merrick Appendix F
Macro Nutrient Tank	8500	3500	"Case 2",
Feed Pump	1500	3800	
Micro Nutrient Tank	4500	3500	
Nutrient Pump	1500	3800	
Caustic Pump	1150	3700	
Caustic Tank	9500	17500	
Iron Tank	550	500	
Iron Metering Pump	850	1550	
Phosphate Tank	2500	2500	
Phosphate pump	850	1550	
			Phoenix Bio-Systems, Inc. Merrick Appendix F
Nutrient System	**$31,400**	**$41,900**	"Case 2",
Prorated Additional Piping			
			Phoenix Bio-Systems, Inc. Merrick Appendix F
Total Cost of Option	$6,013,805		"Case 2",
Overhead Portion	$1,130,000		Design Engineering Fee + Site Preparation
Project Cost Less Overhead	$4,883,805		
Overall Piping & Installation	$518,100		Controls+Temp Control+Piping
Overall Piping & Inst %	10.61%		
Installation Cost Above	$41,900		Per above, extra piping and inst. Prorated
Additional Prorated Installatio	$7,776		
Total Installation Cost	**$49,676**		
Installation Factor	**2.58**		

CLIENT: NREL
PHONE/FAX:
PROJECT NUMBER:
DATE: 5/18/98
TYPE: Anaerobic/Aerobic
LOAD RATE: 12 g/l/d & 0.55 g/l/d
COD: 6510 mg/l & 520 mg/l
FLOW: 1105 gpm

ITEM	Description	Qty	Unit Cost	Installation	Q x UC + I	Totals
Treatability						
Laboratory Analysis						
Preliminary Design						
						$0.00
Equalization						
Dimensions						
Capacity (gal)	500,000	1	450,000.00	100,000.00	550,000.00	
						$550,000.00
Main Reactor						
Dimensions	26' d x 60'hAOS aqua St	4				
Capacity (gal)	950,000	1	750,000.00	175,000.00	925,000.00	
Distribution Manifold	ICM s/s	16	4,950.00	32,500.00	111,700.00	
,06 Overflow collection system	PVC	4	15,500.00	22,000.00	84,000.00	
Separator	10 x 12 FRP Custom	4	28,000.00	38,700.00	150,700.00	
Sample Cocks T-606	1" PVC	36	50.00	1,200.00	3,000.00	
Packing	TriPack PP	6370	12.00	2,500.00	78,940.00	
Insulation		19600	7.00	271,900 EI	137,200.00	
			1,218,640	159,265 pipe inst		$1,490,540.00
				431,165		1649805 1.35 INST
Decarbonator						
Capacity	5,000 gal	1	22,500.00	27,500.00	50,000.00	
Dimensions	8'd x 18				0.00	
Distributor	s/s	1	7,590.00	9,800.00	17,390.00	
Packing	TriPack 3.5 PP	700	12.00	1,500.00	9,900.00	
Demister		1	2,500.00	1,000.00	3,500.00	
Gratings	FRP	1	4,500.00	3,000.00	7,500.00	
Fan	4 hp	1	1,250.00	2,200.00	3,450.00	
Drain						
			46,740	45,000		$91,740.00

Controls						
Field Instruments		1	85,000.00	8,500.00	93,500.00	
Pressure Ind		18	250.00	750.00	5,250.00	
Temp Indicators		18	250.00	750.00	5,250.00	
pH Controller		6	2,500.00	2,000.00	17,000.00	
Biogas Meter		1	4,300.00	1,250.00	5,550.00	
Panel		1	3,800.00	2,250.00	6,050.00	
PLC		1	9,500.00	5,500.00	15,000.00	
Control computer		1	10,500.00	7,500.00	18,000.00	
Software		1	4,000.00	12,000.00	16,000.00	
						$181,600.00 *
Temp Control						
Hot water heater		0	0.00	0.00	0.00	
Heat Exch		2	12,500.00	12,500.00	37,500.00	
						$37,500.00 *
BioGas Scrubber						
Capacity	800 cf	1	10,800.00	7,800.00	18,600.00	
Grating	FRP	1	2,200.00	4,550.00	6,750.00	
Media	650 CF	750	7.50	1,550.00	7,175.00	
						$32,525.00
Piping						
PVC		1	125,000.00	97,000.00	222,000.00	
Heat trace/Insulate		1	32,000.00	45,000.00	77,000.00	
						$299,000.00 *
Macronutrient Tank	M-604					
Tank	5000	1	8,500.00	3,500.00	12,000.00	
Nutrient Feed Pump		1	1,500.00	3,800.00	5,300.00	
Micronutrient Tank						
Tank	3000	1	4,500.00	3,500.00	8,000.00	
Nutrient pump		1	1,500.00	3,800.00	5,300.00	
Caustic Tank						
Caustic Dosing Pump	500 gpd	1	1,150.00	3,700.00	4,850.00	
Tank	5500 gal	1	9,500.00	17,500.00	27,000.00	
Iron Tank	200 gal	1	550.00	500.00	1,050.00	
Metering pump		1	850.00	1,550.00	2,400.00	
Phosphate Tank	1000 gal	1	2,500.00	2,500.00	5,000.00	
Metering pump	50 gpd	1	850.00	1,550.00	2,400.00	
						$73,300.00
			31400	41900		81143
				10% + 7843		
				49743		INST FACT. 2.58

Flare						
Burner	600 CFM	1	10,500.00	4,000.00	14,500.00	
Auto pilot,N-gas,air		1	6,500.00	3,500.00	10,000.00	
						$24,500.00
System Feed Pump						
Cent	1200 gpm, 40' TDH s/s	2	6,500.00	4,600.00	17,600.00	
System Recirc Pump						
Cent	3000 gpm 70' TDH s/s	2	9,500.00	7,500.00	26,500.00	
						$24,500.00
Aerobic Secondary						
Feed Pump	1100 gpm 40' TDH s/s	2	6,500.00	4,200.00	17,200.00	
T-608 Aerated Lagoon T-608	2.5 MM gal	1	100,000.00	750,000.00	850,000.00	
Floating aerators	8 x 50 hp	8	35,000.00	30,000.00	310,000.00	
						$1,177,200.00
Clarifier	275,000 gal	1	225,000.00	125,000.00	350,000.00	
Sludge pumps	2x25hp PD s/s	2	5,500.00	2,900.00	13,900.00	
Effluent pumps/wet wells	2x25hp cent	2	3,500.00	10,500.00	17,500.00	
						$381,400.00
Belt Thickener		1	210,000.00	65,000.00	275,000.00	
Piping	Yard	1	62,000.00	78,000.00	140,000.00	
Sludge holding Tanks/Load out		1	45,000.00	25,000.00	70,000.00	
						$485,000.00
Sand Filters						
VortiSand Filters	0	0	0.00	0.00	0.00	
Surge Tanks	0	0	0.00	0.00	0.00	
						$0.00
Chlorinator						
Hypo Storage/feed Tk	0	0	0.00	0.00	0.00	
Metering system		0	0.00	0.00	0.00	
Contact Tank	0	0	0.00	0.00	0.00	
C.T. Aerator	0	0	0.00	0.00	0.00	
						$0.00

Design Engineering Fee	all	1	475,000.00	475,000.00	
Design Drawings					
Shop Drawings					
Wiring Diagrams					
Power Requirements					
Operating Manuals					
Administratative					
					$475,000.00 *
Site Installation		1		475,000.00	
Site Preparation					
Off-Loading					
Pads					
Power Hook-Up					
Process Hook-Up					
Weather Protection					
Power Outage Protection					
Buildings	Control Building	1		125,000.00	
Fencing					
MCC				55,000.00	
Site Electrical					
Subcontractors					
					$655,000.00 *
Permits and Fees				35,000.00	
Taxes					
Insurance					
					$35,000.00 *
TOTAL					**$6,013,805.00**
Plus 12 % Contingency					**$6,735,461.60**

TOTAL 6,013,805
Less OVHD 4,848,805
PIPE INST 518,100
% OF TOTAL 10.7%

```
Equipment Num        :: M-606
Eqipment Name        :: Biogas Emergency Flare
Associated PFD       :: PFD-P100-A602
Equipment Type       :: MISCELLANEOUS
Equipment Category   :: MISCELLANEOUS
Equipment Description:: FLARE AND PILOT
Number Required      :: 1
Number Spares        :: 0
Scaling Stream       :: 614
Base Cost            :: 20739.00
Cost Basis           :: VENDOR
Cost Year            :: 1998
Base for Scaling     :: 2572.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 1.6800
Install. Factor Basis:: VENDOR
Scale Factor Exponent:: 0.6000
Scale Factor Basis   :: DEFAULT
Material of Const    :: SS
Date Modified        :: 01/13/99
```

Eq. No.	M-606		
Eq. Name	Biogas Handling System		
Associated PFD	A602		
Stream for Design	614		
Stream Description	Reactor Outlet		
Flow Rate	2572	Kg/hr	R9809G
Average MW	22.80		R9809G
Ave Density	0.06	lb/cf	R9809G
Flowrate	1,676	cfm	
Phoenix Bio-Systems, Inc Case 1	**$ 13,000**		Purchase
	150	cfm	
	$ 10,063		Installation w/prorated pipe & inst
	1.77		Installation Factor
Phoenix Bio-Systems, Inc Case 2	**$ 17,000**		
	600	cfm	
	$ 10,122		Installation w/prorated pipe & inst
	1.60		Installation Factor
Scaling Factor	**0.19**		
Average Installation Factor	**1.68**		
Scaled up Cost	**$ 20,739**		for 1676 cfm
Scaling Stream	614		
Scaling Rate	2572		
Scaling Units	Kg/hr		

Case 1 - Capital Cost - Combined Anaerobic and Aerobic Treatment - NREL Dil Acid/ 2stg Softwood

CLIENT:	**NREL**	
PHONE/FAX:		
PROJECT NUMBER:		
DATE:		5/18/98
TYPE:	Anaerobic/Aerobic	
LOAD RATE:	12 g/l/d & 0.55 g/l/d	
COD:	4,173 mg/l and 334 mg/l	
FLOW:	766 gpm	

ITEM	Description	Qty	Unit Cost	Installation	Q x UC + I	Totals
Treatability						
Laboratory Analysis						
Preliminary Design						
						$0.00
Equalization						
Dimensions T-602	36'd x 44'h AOS SI St					
Capacity (gal)	330000 gal	1	325,000.00	86,000.00	411,000.00	
						$411,000.00
Main Reactor						
Dimensions	24'd x 60'h AOS	2				
Capacity (gal)	385,000 gal	1	350,000.00	95,000.00	445,000.00	
Distribution Manifold	ICM s/s	8	4,950.00	10,500.00	50,100.00	
Overflow collection system	PVC	2	3,500.00	7,500.00	14,500.00	
Separator	10 x 12 Custom	2	24,500.00	17,500.00	66,500.00	
Sample Cocks	1" PVC	24	50.00	1,200.00	2,400.00	
Packing	TriPack PP	2600	12.00	2,500.00	33,700.00	
Insulation	9000 ft2	9050	7.00		63,350.00	
						$675,550.00
Decarbonator						
Capacity	3,000 gal	1	14,500.00	17,500.00	32,000.00	
Dimensions	6'd x 18'h				0.00	
Distributor	s/s	1	4,850.00	8,700.00	13,550.00	
Packing	TriPack 3.5 PP	400	12.00	1,500.00	6,300.00	
Demister		1	1,500.00	1,000.00	2,500.00	
Gratings	FRP	1	3,500.00	3,000.00	6,500.00	
Fan	3 hp	1	1,250.00	2,200.00	3,450.00	
Drain						
						$64,300.00

Controls						
Field Instruments		1	85,000.00	8,500.00	93,500.00	
Pressure Ind		12	250.00	750.00	3,750.00	
Temp Indicators		12	250.00	750.00	3,750.00	
pH Controller		4	2,500.00	2,000.00	12,000.00	
Biogas Meter		1	4,300.00	1,250.00	5,550.00	
Panel		1	3,800.00	2,250.00	6,050.00	
PLC		1	9,500.00	5,500.00	15,000.00	
Control computer		1	10,500.00	7,500.00	18,000.00	
Software		1	4,000.00	12,000.00	16,000.00	
						$173,600.00
Temp Control						
Hot water heater		0	0.00	0.00	0.00	
Heat Exch		2	6,500.00	14,500.00	27,500.00	
						$27,500.00
BioGas Scrubber						
Capacity	300 cf	1	6,500.00	7,600.00	14,100.00	
Grating	FRP	1	1,800.00	3,350.00	5,150.00	
Media	280	280	7.50	1,550.00	3,650.00	
						$22,900.00
Piping						
PVC		1	75,000.00	55,000.00	130,000.00	
Heat trace/Insulate		1	12,500.00	28,000.00	40,500.00	
						$170,500.00
Macronutrient Tank						
Tank	5000	1	8,500.00	3,500.00	12,000.00	
Nutrient Feed Pump		1	1,500.00	3,800.00	5,300.00	
Micronutrient Tank						
Tank	3000	1	4,500.00	3,500.00	8,000.00	
Nutrient pump		1	1,500.00	3,800.00	5,300.00	
Caustic Tank						
Caustic Dosing Pump	500 gpd	1	1,150.00	3,700.00	4,850.00	
Tank	5500 gal	1	9,500.00	17,500.00	27,000.00	
Iron Tank	200 gal	1	550.00	500.00	1,050.00	
Metering pump		1	850.00	1,550.00	2,400.00	
Phosphate Tank	1000 gal	1	2,500.00	2,500.00	5,000.00	
Metering pump	50 gpd	1	850.00	1,550.00	2,400.00	
			$31,400	41900		$73,300.00

M604

ML06

Flare						
Burner	**150 CFM**	1	8,500.00	4,000.00	12,500.00	
Auto pilot,N-gas,air		1	4,500.00	3,500.00	8,000.00	
				+ 2562.5 $10062.50		$20,500.00
System Feed Pump						
Cent	766 gpm, 40' TDH s/s	2	4,900.00	2,700.00	12,500.00	
System Recirc Pump						
Cent	1500 gpm 70' TDH s/s	2	8,000.00	4,500.00	20,500.00	
						$20,500.00
Aerobic Secondary						
Feed Pump	766 gpm 40' TDH s/s	2	4,900.00	3,500.00	13,300.00	
Aerated Lagoon	0.9 mgal	1		500,000.00	500,000.00	
Floating aerators	4x25 hp, 2 x 50 hp	6	25,000.00	22,000.00	172,000.00	
						$685,300.00
Clarifier	180,000 gal	1	155,000.00	115,000.00	270,000.00	
Sludge pumps	2x25hp PD s/s	2	5,500.00	2,900.00	13,900.00	
Effluent pumps/wet wells	2x25hp cent	2	3,500.00	10,500.00	17,500.00	
						$301,400.00
Belt Thickener		1	110,000.00	42,000.00	152,000.00	
Piping	Yard	1	42,000.00	67,000.00	109,000.00	
Sludge holding Tanks/Load out		1	45,000.00	25,000.00	70,000.00	
						$331,000.00
Sand Filters						
VortiSand Filters	0	0	0.00	0.00	0.00	
Surge Tanks	0	0	0.00	0.00	0.00	
						$0.00
Chlorinator						
Hypo Storage/feed Tk	0	0	0.00	0.00	0.00	
Metering system		0	0.00	0.00	0.00	
Contact Tank	0	0	0.00	0.00	0.00	
C.T. Aerator	0	0	0.00	0.00	0.00	
						$0.00

Design Engineering Fee	all	1	250,000.00	250,000.00	
Design Drawings					
Shop Drawings					
Wiring Diagrams					
Power Requirements					
Operating Manuals					
Administratative					
					$250,000.00
Site Installation		1		295,000.00	
Site Preparation					
Off-Loading					
Pads					
Power Hook-Up					
Process Hook-Up					
Weather Protection					
Power Outage Protection					
Buildings	Control Building	1		125,000.00	
Fencing					
MCC				55,000.00	
Site Electrical					
Subcontractors					
					$475,000.00
Permits and Fees				35,000.00	
Taxes					
Insurance					
					$35,000.00
TOTAL					**$3,737,350.0**
Plus 12 % Contingency					**$4,185,832.0**

3,737,350
less what* 2,977,350
PIPING * 371600
PIPING % 12.5%

CLIENT: NREL
PHONE/FAX:
PROJECT NUMBER:
DATE: 5/18/98
TYPE: Anaerobic/Aerobic
LOAD RATE: 12 g/l/d & 0.55 g/l/d
COD: 6510 mg/l & 520 mg/l
FLOW: 1105 gpm

ITEM	Description	Qty	Unit Cost	Installation	Q x UC + I	Totals
Treatability						
Laboratory Analysis						
Preliminary Design						
						$0.00
Equalization						
Dimensions						
Capacity (gal)	500,000	1	450,000.00	100,000.00	550,000.00	
						$550,000.00
Main Reactor						
Dimensions	26' d x 60'hAOS aqua St	4				
Capacity (gal)	950,000	1	750,000.00	175,000.00	925,000.00	
Distribution Manifold	ICM s/s	16	4,950.00	32,500.00	111,700.00	
Overflow collection system	PVC	4	15,500.00	22,000.00	84,000.00	
Separator	10 x 12 FRP Custom	4	28,000.00	38,700.00	150,700.00	
Sample Cocks T-606	1" PVC	36	50.00	1,200.00	3,000.00	
Packing	TriPack PP	6370	12.00	2,500.00	78,940.00	
Insulation		19600	7.00		137,200.00	
			1,218,640	271,900 e) 159,265 pipinst 431,165		$1,490,540.00
						1649305 135 inst
Decarbonator						
Capacity	5,000 gal	1	22,500.00	27,500.00	50,000.00	
Dimensions	8'd x 18				0.00	
Distributor	s/s	1	7,590.00	9,800.00	17,390.00	
Packing	TriPack 3.5 PP	700	12.00	1,500.00	9,900.00	
Demister		1	2,500.00	1,000.00	3,500.00	
Gratings	FRP	1	4,500.00	3,000.00	7,500.00	
Fan	4 hp	1	1,250.00	2,200.00	3,450.00	
Drain						
			46,740	45,000		$91,740.00

Controls						
Field Instruments		1	85,000.00	8,500.00	93,500.00	
Pressure Ind		18	250.00	750.00	5,250.00	
Temp Indicators		18	250.00	750.00	5,250.00	
pH Controller		6	2,500.00	2,000.00	17,000.00	
Biogas Meter		1	4,300.00	1,250.00	5,550.00	
Panel		1	3,800.00	2,250.00	6,050.00	
PLC		1	9,500.00	5,500.00	15,000.00	
Control computer		1	10,500.00	7,500.00	18,000.00	
Software		1	4,000.00	12,000.00	16,000.00	
						$181,600.00 *
Temp Control						
Hot water heater		0	0.00	0.00	0.00	
Heat Exch		2	12,500.00	12,500.00	37,500.00	
						$37,500.00 *
BioGas Scrubber						
Capacity	800 cf	1	10,800.00	7,800.00	18,600.00	
Grating	FRP	1	2,200.00	4,550.00	6,750.00	
Media	650 CF	750	7.50	1,550.00	7,175.00	
						$32,525.00
Piping						
PVC		1	125,000.00	97,000.00	222,000.00	
Heat trace/Insulate		1	32,000.00	45,000.00	77,000.00	
						$299,000.00 *
Macronutrient Tank						
Tank	5000	1	8,500.00	3,500.00	12,000.00	
Nutrient Feed Pump		1	1,500.00	3,800.00	5,300.00	
Micronutrient Tank						
Tank	3000	1	4,500.00	3,500.00	8,000.00	
Nutrient pump		1	1,500.00	3,800.00	5,300.00	
Caustic Tank						
Caustic Dosing Pump	500 gpd	1	1,150.00	3,700.00	4,850.00	
Tank	5500 gal	1	9,500.00	17,500.00	27,000.00	
Iron Tank	200 gal	1	550.00	500.00	1,050.00	
Metering pump		1	850.00	1,550.00	2,400.00	
Phosphate Tank	1000 gal	1	2,500.00	2,500.00	5,000.00	
Metering pump	50 gpd	1	850.00	1,550.00	2,400.00	
						$73,300.00
			31400	41900		81143
				10%+ 7843		
				49743		INST FACT. 2.58

	Flare						
-606	Burner M606	600 CFM	1	10,500.00	4,000.00	14,500.00	
	Auto pilot,N-gas,air		1	6,500.00	3,500.00	10,000.00	
				10.7%	+2621.50 10121.50		$24,500.00
	System Feed Pump						
	Cent	1200 gpm, 40' TDH s/s	2	6,500.00	4,600.00	17,600.00	
	System Recirc Pump						
	Cent	3000 gpm 70' TDH s/s	2	9,500.00	7,500.00	26,500.00	
							$24,500.00
	Aerobic Secondary						
	Feed Pump	1100 gpm 40' TDH s/s	2	6,500.00	4,200.00	17,200.00	
T-608	Aerated Lagoon T608	2.5 MM gal	1	100,000.00	750,000.00	850,000.00	
	Floating aerators	8 x 50 hp	8	35,000.00	30,000.00	310,000.00	
							$1,177,200.00
	Clarifier	275,000 gal	1	225,000.00	125,000.00	350,000.00	
	Sludge pumps	2x25hp PD s/s	2	5,500.00	2,900.00	13,900.00	
	Effluent pumps/wet wells	2x25hp cent	2	3,500.00	10,500.00	17,500.00	
							$381,400.00
	Belt Thickener		1	210,000.00	65,000.00	275,000.00	
	Piping	Yard	1	62,000.00	78,000.00	140,000.00	
	Sludge holding Tanks/Load out		1	45,000.00	25,000.00	70,000.00	
							$485,000.00
	Sand Filters						
	VortiSand Filters	0	0	0.00	0.00	0.00	
	Surge Tanks	0	0	0.00	0.00	0.00	
							$0.00
	Chlorinator						
	Hypo Storage/feed Tk	0	0	0.00	0.00	0.00	
	Metering system		0	0.00	0.00	0.00	
	Contact Tank	0	0	0.00	0.00	0.00	
	C.T. Aerator	0	0	0.00	0.00	0.00	
							$0.00

Design Engineering Fee	all	1	475,000.00	475,000.00	
Design Drawings					
Shop Drawings					
Wiring Diagrams					
Power Requirements					
Operating Manuals					
Administratative					
					$475,000.00
Site Installation		1		475,000.00	
Site Preparation					
Off-Loading					
Pads					
Power Hook-Up					
Process Hook-Up					
Weather Protection					
Power Outage Protection					
Buildings	Control Building	1		125,000.00	
Fencing					
MCC				55,000.00	
Site Electrical					
Subcontractors					
					$655,000.00
Permits and Fees				35,000.00	
Taxes					
Insurance					
					$35,000.00
TOTAL					**$6,013,805.00**
Plus 12 % Contingency					**$6,735,461.60**

TOTAL 6,013,805
Loss OVHD 4,848,805
PIP & INST 518,100
% of TOTAL 10.7%

Wooley, Robert

From: Dick.Voiles@merrick.com
Sent: Monday, November 16, 1998 3:00 PM
To: robert_wooley@nrel.gov
Cc: Jim.Sharpe@merrick.com; James.Kassian@merrick.com; Fran.Ferraro@merrick.com; Dick.Voiles@merrick.com
Subject: Anaerobic Digestor Offgas

I just spoke to Joe about an emergency flare on this gas and he said it is essential. So we better add it to the estimate. Joe has already given us a price that we can scale from.

These are stainless steel and are 12 to 25 feet tall. Since they are low pressure they are large in diameter - I would not doubt that ours could hit 30" in diameter. In a refinery or gas plant, flares are a couple of hundred of feet tall based on the largest ground level radiation not frying any operators. I suggest we add this flare to our further work list as our combustibles loading is a lot higher than Joe is used to seeing.

Joe explained that the scrubber on this gas is actually an iron sponge absorber. When I approached SulfaTreat (a proprietary iron sponge process vendor) with our H2S loading they eliminated themselves as not being practical for such a large load. This ion exchange rinse is really a problem.

```
Equipment Num        :: M-612
Eqipment Name        :: Filter Precoat System
Associated PFD       :: PFD-P100-A603
Equipment Category   :: MISCELLANEOUS
Equipment Description:: Tank, Agitator, Pump
Number Required      :: 1
Number Spares        :: 0
Base Cost            :: 3000.00
Cost Basis           :: MERRICK98
Cost Year            :: 1998
Install. Factor      :: 1.4000
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WM612
Utility Type         :: POWER
Date Modified        :: 12/22/98
Notes                :: Expected Power Req: 4 kW.
```

Eq. No.	M-612		
Eq. Name	Filter Precoat System		
Associated PFD	A603		
Stream for Design	NA		Too small to Scale
Power Requirement	5	hp	Estimated
Cost	**$ 3,000**		Merrick Estimate for Small Tank and Pump
Year	**1998**		
Scaling Stream	NA		

```
Equipment Num        :: P-602
Eqipment Name        :: Anaerobic Reactor Feed Pump
Associated PFD       :: PFD-P100-A602
Equipment Type       :: CENTRIFUGAL
Equipment Category   :: PUMP
Equipment Description:: 876 gpm, 150 ft head
Number Required      :: 1
Number Spares        :: 1
Scaling Stream       :: 612
Base Cost            :: 11400.00
Cost Basis           :: ICARUS
Cost Year            :: 1997
Base for Scaling     :: 188129.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 2.8000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.7900
Scale Factor Basis   :: GARRETT
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WP602
Utility Type         :: POWER
Date Modified        :: 12/22/98
Notes                :: Expected Power Req: 41 kW.
```

Eq. No.	P-602		
Eq. Name	Anerobic Digestor Feed Pump		
Associated PFD	A602		
Stream for Design	612		
Stream Description	Pump Inlet		
Flow Rate	188129	Kg/hr	R9809G
Liquid Density	0.95	g/cm^3	R9809G
Solid Density	0.00	g/cm^3	R9809G
Frac Solids	0.000		
Flowrate	876.3	gpm	
Outlet Head	150.0	ft	
Estimated Power	55	hp	
	41	kW	
Cost Estimation			
ICARUS- 1997	**$ 11,400**	CS	
	$ 10,600	CI	
	$ 15,200	SS	
Scaling Stream	612		
Scaling Rate	188129		
Scaling Units	Kg/hr		

P-602 CP - 100 P-602

EQUIPMENT ITEM DESIGN DATA SHEET

ANSI

NO.	ITEM	VALUE SPECIFIED BY USER	VALUE USED BY SYSTEM	UNITS
	EQUIPMENT DESIGN DATA			
1.	MATERIAL SYMBOL	CS	CS	
2.	DESIGN TEMPERATURE		120.0	DEG F
3.	DESIGN PRESSURE		150.0	PSIG
4.	HEAD	150.0	150.0	FEET
5.	ASA RATING		150	
6.	DRIVER POWER		50.00	HP
7.	DRIVER SPEED		1800.0	RPM
8.	DRIVER TYPE SYMBOL		MOTOR	
9.	PUMP EFFICIENCY		82.00	PERCENT
	SEAL DATA			
10.	SEAL TYPE		SNGL	
11.	PRIMARY SEAL PIPE PLAN		11	
12.	SEAL PIPING PIPE TYPE		WELD	
13.	SEAL PIPING MATERIAL		A 106	
	PROCESS DESIGN DATA			
14.	CAPACITY	876.0	876.0	GPM
15.	FLUID DENSITY		62.43	PCF
16.	FLUID VISCOSITY		1.000	CPOISE
17.	RESULTING DESIGN VALUE		0.0571	HP/GPM
18.	CAPACITY*HEAD		131400	GPM -FT
	WEIGHT DATA			
19.	PUMP		530	LBS
20.	MOTOR		530	LBS
21.	BASE PLATE		110	LBS
22.	FITTINGS, ETC.		100	LBS
23.	TOTAL WEIGHT		1300	LBS
	VENDOR COST DATA			
24.	MOTOR		2100	USD
25.	MATERIAL COMPONENT COST		2055	USD
26.	SHOP MANPOWER COST		2093	USD
27.	SHOP OVERHEAD		2135	USD
28.	GENERAL OFFICE OVERHEAD		1425	USD
29.	PROFIT		1592	USD
30.	TOTAL COST		11400	USD
31.	RESULTING UNIT COST		8.769	USD/LBS
32.	RESULTING UNIT COST		13.01	USD/GPM
33.	RESULTING UNIT COST		228.0	USD/HP

	MATERIAL USD	MANPOWER USD	MANPOWER MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	11400.	935.	50	0.082
PIPING	12288.	4532.	245	0.369
CIVIL	356.	696.	44	1.954
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	5963.	1466.	76	0.246
ELECTRICAL	427.	697.	35	1.631
INSULATION	0.	0.	0	0.000
PAINT	475.	777.	57	1.636
SUBTOTAL	30910.	9103.	507	0.294

INSTALLED DIRECT COST 40000. INST'L COST/PE RATIO 3.509

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:53:19

```
Equipment Num        :: P-606
Eqipment Name        :: Aerobic Digestor Feed Pump
Associated PFD       :: PFD-P100-A602
Equipment Type       :: CENTRIFUGAL
Equipment Category   :: PUMP
Equipment Description:: 830 gpm, 150 ft head
Number Required      :: 1
Number Spares        :: 1
Scaling Stream       :: 618
Base Cost            :: 10700.00
Cost Basis           :: ICARUS
Cost Year            :: 1997
Base for Scaling     :: 185782.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 2.8000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.7900
Scale Factor Basis   :: GARRETT
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WP606
Utility Type         :: POWER
Date Modified        :: 12/22/98
Notes                :: Expected Power Req: 41 kW.
```

Eq. No.	P-606		
Eq. Name	Aerobic Digestor Feed Pump		
Associated PFD	A602		
Stream for Design	618		
Stream Description	Pump Inlet		
Flow Rate	185782	Kg/hr	R9809G
Liquid Density	0.98	g/cm^3	R9809G
Solid Density	0.00	g/cm^3	R9809G
Frac Solids	0.000		
Flowrate	831.1	gpm	
Outlet Pressure	4.2	atm	
Outlet Head	150.0	ft	
Estimated Power	54	hp	
	41	kW	
ICARUS- 1997	**$10,700**	CS	
	$9,900	CI	
	$14,500	SS	
Scaling Stream	618		
Scaling Rate	185782		
Scaling Units	Kg/hr		

P-606 CP - 100 P-606

EQUIPMENT ITEM DESIGN DATA SHEET

ANSI

NO.	ITEM	VALUE SPECIFIED BY USER	VALUE USED BY SYSTEM	UNITS
	EQUIPMENT DESIGN DATA			
1.	MATERIAL SYMBOL	CS	CS	
2.	DESIGN TEMPERATURE		120.0	DEG F
3.	DESIGN PRESSURE		150.0	PSIG
4.	HEAD	150.0	150.0	FEET
5.	ASA RATING		150	
6.	DRIVER POWER		40.00	HP
7.	DRIVER SPEED		1800.0	RPM
8.	DRIVER TYPE SYMBOL		MOTOR	
9.	PUMP EFFICIENCY		82.00	PERCENT
	SEAL DATA			
10.	SEAL TYPE		SNGL	
11.	PRIMARY SEAL PIPE PLAN		11	
12.	SEAL PIPING PIPE TYPE		WELD	
13.	SEAL PIPING MATERIAL		A 106	
	PROCESS DESIGN DATA			
14.	CAPACITY	831.0	831.0	GPM
15.	FLUID DENSITY		62.43	PCF
16.	FLUID VISCOSITY		1.000	CPOISE
17.	RESULTING DESIGN VALUE		0.0481	HP/GPM
18.	CAPACITY*HEAD		124650	GPM -FT
	WEIGHT DATA			
19.	PUMP		530	LBS
20.	MOTOR		450	LBS
21.	BASE PLATE		110	LBS
22.	FITTINGS, ETC.		100	LBS
23.	TOTAL WEIGHT		1200	LBS
	VENDOR COST DATA			
24.	MOTOR		1700	USD
25.	MATERIAL COMPONENT COST		2052	USD
26.	SHOP MANPOWER COST		2050	USD
27.	SHOP OVERHEAD		2091	USD
28.	GENERAL OFFICE OVERHEAD		1342	USD
29.	PROFIT		1465	USD
30.	TOTAL COST		10700	USD
31.	RESULTING UNIT COST		8.917	USD/LBS
32.	RESULTING UNIT COST		12.88	USD/GPM
33.	RESULTING UNIT COST		267.5	USD/HP

	MATERIAL USD	MANPOWER USD	MANPOWER MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	10700.	856.	46	0.080
PIPING	12276.	4521.	244	0.368
CIVIL	328.	797.	51	2.427
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	5963.	1466.	76	0.246
ELECTRICAL	427.	697.	35	1.631
INSULATION	0.	0.	0	0.000
PAINT	472.	770.	56	1.632
SUBTOTAL	30166.	9107.	508	0.302

INSTALLED DIRECT COST 39300. INST'L COST/PE RATIO 3.673

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:53:19

Equipment Num	:: P-608
Eqipment Name	:: Aerobic Sludge Recycle Pump
Associated PFD	:: PFD-P100-A603
Equipment Type	:: SLURRY
Equipment Category	:: PUMP
Equipment Description	:: 2.5 gpm, 150 ft head
Number Required	:: 1
Number Spares	:: 0
Scaling Stream	:: 625
Base Cost	:: 11100.00
Cost Basis	:: ICARUS
Cost Year	:: 1997
Base for Scaling	:: 5862.000
Base Type	:: FLOW
Base Units	:: KG/HR
Install. Factor	:: 1.4000
Install. Factor Basis	:: DELTA-T98
Scale Factor Exponent	:: 0.7900
Scale Factor Basis	:: GARRETT
Material of Const	:: SS316
Utility Calc.	:: ASPEN FORT BLCK
Utility Stream	:: WP608
Utility Type	:: POWER
Date Modified	:: 12/22/98
Notes	:: Expected Power Req: 1 kW. Operates only part time. Use same pump as P-610. Therefore, no spare.

Eq. No.	P-608		
Eq. Name	Aerobic Sludge Recycle Pump		
Associated PFD	A603		
Stream for Design	625		Operates Part time, same as P-610, serves as spare
Stream Description	Pump Inlet		
Flow Rate	5862	Kg/hr	R9809G
Average Density	1.02	g/cm^3	R9809G
Frac Solids	0.046		
Flowrate	25.3	gpm	
Outlet Head	150.0	ft	
Estimated Power	2	hp	
	1	kW	
Slurry Pump			
Cost Estimation			
ICARUS- 1997	**$ 11,100**	SS316	Only material avilable in ICARUS for Slurry Pump
Scaling Stream	625		
Scaling Rate	5862		
Scaling Units	Kg/hr		

P-610 P - 100 P-610

COMPONENT DATA SHEET

SLURRY

CODE OF ACCOUNT: 167

COMPONENT DESIGN DATA:

MATERIAL	SS316
CAPACITY	25.00 GPM
HEAD	150.00 FEET
DRIVER POWER	1.50 HP
SPEED	1800.00 RPM

COST DATA:

ESTIMATED PURCHASE COST USD 11100.

	MATERIAL USD	MANPOWER USD	MANPOWER MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	11100.	186.	10	0.017
PIPING	2294.	3848.	207	1.678
CIVIL	127.	430.	27	3.385
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	1273.	54.	3	0.043
ELECTRICAL	393.	668.	34	1.699
INSULATION	0.	0.	0	0.000
PAINT	0.	0.	0	0.000
SUBTOTAL	15187.	5186.	281	0.341

INSTALLED DIRECT COST 20400. INST'L COST/PE RATIO 1.838

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:53:19

```
Equipment Num        :: P-610
Eqipment Name        :: Aerobic Sludge Pump
Associated PFD       :: PFD-P100-A603
Equipment Type       :: SLURRY
Equipment Category   :: PUMP
Equipment Description:: 25.3 gpm, 150 ft head
Number Required      :: 1
Number Spares        :: 0
Scaling Stream       :: 625
Base Cost            :: 11100.00
Cost Basis           :: ICARUS
Cost Year            :: 1997
Base for Scaling     :: 5862.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 1.4000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.7900
Scale Factor Basis   :: GARRETT
Material of Const    :: SS316
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WP610
Utility Type         :: POWER
Date Modified        :: 12/22/98
Notes                :: Expected power Req: 1 kW.  SS 316 only material
                        available in Icarus.  P-608 serves as a spare.
```

Eq. No.	P-610		
Eq. Name	Aerobic Sludge Pump		
Associated PFD	A603		
Stream for Design	625		
Stream Description	Pump Inlet		
Flow Rate	5862	Kg/hr	R9809G
Average Density	1.02	g/cm^3	R9809G
Frac Solids	0.046		
Flowrate	25.3	gpm	
Outlet Head	150.0	ft	
Estimated Power	2	hp	
	1	kW	
Slurry Pump			
Cost Estimation			
ICARUS- 1997	**$ 11,100**	SS316	Only material available in ICARUS for Slurry Pump
Scaling Stream	625		
Scaling Rate	5862		
Scaling Units	Kg/hr		

P-610 P - 100 P-610

COMPONENT DATA SHEET

SLURRY

CODE OF ACCOUNT: 167

COMPONENT DESIGN DATA:

MATERIAL	SS316
CAPACITY	25.00 GPM
HEAD	150.00 FEET
DRIVER POWER	1.50 HP
SPEED	1800.00 RPM

COST DATA:

ESTIMATED PURCHASE COST USD 11100.

	---MATERIAL--	*** M A N P O W E R ***		L/M RATIO
	USD	USD	MANHOURS	USD/USD
EQUIPMENT&SETTING	11100.	186.	10	0.017
PIPING	2294.	3848.	207	1.678
CIVIL	127.	430.	27	3.385
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	1273.	54.	3	0.043
ELECTRICAL	393.	668.	34	1.699
INSULATION	0.	0.	0	0.000
PAINT	0.	0.	0	0.000
SUBTOTAL	15187.	5186.	281	0.341

INSTALLED DIRECT COST 20400. INST'L COST/PE RATIO 1.838

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:53:19

```
Equipment Num        :: P-611
Eqipment Name        :: Aerobic Digestion Outlet Pump
Associated PFD       :: PFD-P100-A603
Equipment Type       :: CENTRIFUGAL
Equipment Category   :: PUMP
Equipment Description:: 828 gpm, 150' head
Number Required      :: 1
Number Spares        :: 1
Scaling Stream       :: 621
Base Cost            :: 10700.00
Cost Basis           :: ICARUS
Cost Year            :: 1997
Base for Scaling     :: 187827.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 2.8000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.7900
Scale Factor Basis   :: GARRETT
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WP611
Utility Type         :: POWER
Date Modified        :: 12/22/98
Notes                :: Expected power Req: 41 kW.
```

Eq. No.	P-611		
Eq. Name	Aerobic Digestion Outlet Pump		
Associated PFD	A603		
Stream for Design	621		
Stream Description	Pump Inlet		
Flow Rate	187827	Kg/hr	R9809G
Liquid Density	1.00	g/cm^3	R9809G
Frac Solids	0.001		
Flowrate	828.4	gpm	
Outlet Head	150	ft	
Estimated Power	55	hp	
	41	kW	
Cost Estimation			
ICARUS- 1997	**$ 10,700**	CS	
	$ 9,900	CI	
	$ 14,500	SS	
Scaling Stream	621		
Scaling Rate	187827		
Scaling Units	Kg/hr		

P-611 CP - 100 P-611

EQUIPMENT ITEM DESIGN DATA SHEET

ANSI

NO.	ITEM	VALUE SPECIFIED BY USER	VALUE USED BY SYSTEM	UNITS
	EQUIPMENT DESIGN DATA			
1.	MATERIAL SYMBOL		CS	
2.	DESIGN TEMPERATURE		120.0	DEG F
3.	DESIGN PRESSURE		150.0	PSIG
4.	HEAD	150.0	150.0	FEET
5.	ASA RATING		150	
6.	DRIVER POWER		40.00	HP
7.	DRIVER SPEED		1800.0	RPM
8.	DRIVER TYPE SYMBOL		MOTOR	
9.	PUMP EFFICIENCY		82.00	PERCENT
	SEAL DATA			
10.	SEAL TYPE		SNGL	
11.	PRIMARY SEAL PIPE PLAN		11	
12.	SEAL PIPING PIPE TYPE		WELD	
13.	SEAL PIPING MATERIAL		A 106	
	PROCESS DESIGN DATA			
14.	CAPACITY	828.0	828.0	GPM
15.	FLUID DENSITY		62.43	PCF
16.	FLUID VISCOSITY		1.000	CPOISE
17.	RESULTING DESIGN VALUE		0.0483	HP/GPM
18.	CAPACITY*HEAD		124200	GPM -FT
	WEIGHT DATA			
19.	PUMP		530	LBS
20.	MOTOR		450	LBS
21.	BASE PLATE		110	LBS
22.	FITTINGS, ETC.		100	LBS
23.	TOTAL WEIGHT		1200	LBS
	VENDOR COST DATA			
24.	MOTOR		1700	USD
25.	MATERIAL COMPONENT COST		2052	USD
26.	SHOP MANPOWER COST		2047	USD
27.	SHOP OVERHEAD		2088	USD
28.	GENERAL OFFICE OVERHEAD		1341	USD
29.	PROFIT		1472	USD
30.	TOTAL COST		10700	USD
31.	RESULTING UNIT COST		8.917	USD/LBS
32.	RESULTING UNIT COST		12.92	USD/GPM
33.	RESULTING UNIT COST		267.5	USD/HP

	MATERIAL USD	MANPOWER USD	MANPOWER MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	10700.	856.	46	0.080
PIPING	12276.	4521.	244	0.368
CIVIL	328.	797.	51	2.427
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	5963.	1466.	76	0.246
ELECTRICAL	427.	697.	35	1.631
INSULATION	0.	0.	0	0.000
PAINT	472.	770.	56	1.632
SUBTOTAL	30166.	9107.	508	0.302

INSTALLED DIRECT COST 39300. INST'L COST/PE RATIO 3.673

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:53:19

```
Equipment Num        :: P-614
Eqipment Name        :: Sludge Filtrate Recycle Pump
Associated PFD       :: PFD-P100-A603
Equipment Type       :: CENTRIFUGAL
Equipment Category   :: PUMP
Equipment Description:: 22 gpm, 150' head
Number Required      :: 1
Number Spares        :: 1
Scaling Stream       :: 627
Base Cost            :: 6100.00
Cost Basis           :: ICARUS
Cost Year            :: 1997
Base for Scaling     :: 4885.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 2.8000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.7900
Scale Factor Basis   :: GARRETT
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WP614
Utility Type         :: POWER
Date Modified        :: 12/22/98
Notes                :: Expected Power Req: 1 kW.
```

Eq. No.	P-614		
Eq. Name	Sludge Filtrate Recycle Pump		
Associated PFD	A603		
Stream for Design	627		
Stream Description	Pump Inlet		
Flow Rate	4885	Kg/hr	R9809G
Liquid Density	1.00	g/cm^3	R9809G
Frac Solids	0.000		
Flowrate	21.6	gpm	
Outlet Head	150.0	ft	
Estimated Power	1.4	hp	
	1.1	kW	
Cost Estimation			
ICARUS- 1997	**$ 6,100**	CS	
	$ 5,600	CI	
	$ 8,600	SS	
Scaling Stream	627		
Scaling Rate	4885		
Scaling Units	Kg/hr		

P-614 CP - 100 P-614

EQUIPMENT ITEM DESIGN DATA SHEET

ANSI

NO.	ITEM	VALUE SPECIFIED BY USER	VALUE USED BY SYSTEM	UNITS
	EQUIPMENT DESIGN DATA			
1.	MATERIAL SYMBOL		CS	
2.	DESIGN TEMPERATURE		120.0	DEG F
3.	DESIGN PRESSURE		150.0	PSIG
4.	HEAD	150.0	150.0	FEET
5.	ASA RATING		150	
6.	DRIVER POWER		2.000	HP
7.	DRIVER SPEED		1800.0	RPM
8.	DRIVER TYPE SYMBOL		MOTOR	
9.	PUMP EFFICIENCY		50.00	PERCENT
	SEAL DATA			
10.	SEAL TYPE		SNGL	
11.	PRIMARY SEAL PIPE PLAN		11	
12.	SEAL PIPING PIPE TYPE		WELD	
13.	SEAL PIPING MATERIAL		A 106	
	PROCESS DESIGN DATA			
14.	CAPACITY	22.00	22.00	GPM
15.	FLUID DENSITY		62.43	PCF
16.	FLUID VISCOSITY		1.000	CPOISE
17.	RESULTING DESIGN VALUE		0.0909	HP/GPM
18.	CAPACITY*HEAD		3300	GPM -FT
	WEIGHT DATA			
19.	PUMP		440	LBS
20.	MOTOR		70	LBS
21.	BASE PLATE		90	LBS
22.	FITTINGS, ETC.		80	LBS
23.	TOTAL WEIGHT		680	LBS
	VENDOR COST DATA			
24.	MOTOR		190	USD
25.	MATERIAL COMPONENT COST		1680	USD
26.	SHOP MANPOWER COST		1302	USD
27.	SHOP OVERHEAD		1328	USD
28.	GENERAL OFFICE OVERHEAD		765	USD
29.	PROFIT		835	USD
30.	TOTAL COST		6100	USD
31.	RESULTING UNIT COST		8.971	USD/LBS
32.	RESULTING UNIT COST		277.3	USD/GPM
33.	RESULTING UNIT COST		3050.0	USD/HP

	MATERIAL USD	MANPOWER USD	MANPOWER MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	6100.	458.	25	0.075
PIPING	1525.	3654.	196	2.397
CIVIL	131.	438.	28	3.341
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	4032.	1466.	76	0.364
ELECTRICAL	393.	668.	34	1.699
INSULATION	0.	0.	0	0.000
PAINT	98.	211.	15	2.159
SUBTOTAL	12279.	6896.	374	0.562

INSTALLED DIRECT COST 19200. INST'L COST/PE RATIO 3.148

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:53:19

```
Equipment Num        :: P-616
Eqipment Name        :: Treated Water Pump
Associated PFD       :: PFD-P100-A603
Equipment Type       :: CENTRIFUGAL
Equipment Category   :: PUMP
Equipment Description:: 803 gpm, 100 ft head
Number Required      :: 1
Number Spares        :: 1
Scaling Stream       :: 624
Base Cost            :: 10600.00
Cost Basis           :: ICARUS
Cost Year            :: 1997
Base for Scaling     :: 181965.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 2.8000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.7900
Scale Factor Basis   :: GARRETT
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WP616
Utility Type         :: POWER
Date Modified        :: 12/22/98
Notes                :: Expected Power Req: 40 kW.
```

Eq. No.	P-616		
Eq. Name	Treated Water Pump		
Associated PFD	A603		
Stream for Design	624		
Stream Description	Pump Inlet		
Flow Rate	181965	Kg/hr	R9809G
Liquid Density	1.00	g/cm^3	R9809G
Frac Solids	0.000		
Flowrate	803.4	gpm	
Outlet Head	150.0	ft	
Estimated Power	53	hp	
	40	kW	
Cost Estimation			
ICARUS- 1997	**$ 9,900**	CS	
	$ 10,600	CI	
	$ 14,400	SS	
Scaling Stream	624		
Scaling Rate	181965		
Scaling Units	Kg/hr		

P-616 CP - 100 P-616

EQUIPMENT ITEM DESIGN DATA SHEET

ANSI

NO.	ITEM	VALUE SPECIFIED BY USER	VALUE USED BY SYSTEM	UNITS
	EQUIPMENT DESIGN DATA			
1.	MATERIAL SYMBOL		CS	
2.	DESIGN TEMPERATURE		120.0	DEG F
3.	DESIGN PRESSURE		150.0	PSIG
4.	HEAD	150.0	150.0	FEET
5.	ASA RATING		150	
6.	DRIVER POWER		40.00	HP
7.	DRIVER SPEED		1800.0	RPM
8.	DRIVER TYPE SYMBOL		MOTOR	
9.	PUMP EFFICIENCY		82.00	PERCENT
	SEAL DATA			
10.	SEAL TYPE		SNGL	
11.	PRIMARY SEAL PIPE PLAN		11	
12.	SEAL PIPING PIPE TYPE		WELD	
13.	SEAL PIPING MATERIAL		A 106	
	PROCESS DESIGN DATA			
14.	CAPACITY	803.0	803.0	GPM
15.	FLUID DENSITY		62.43	PCF
16.	FLUID VISCOSITY		1.000	CPOISE
17.	RESULTING DESIGN VALUE		0.0498	HP/GPM
18.	CAPACITY*HEAD		120450	GPM -FT
	WEIGHT DATA			
19.	PUMP		530	LBS
20.	MOTOR		450	LBS
21.	BASE PLATE		110	LBS
22.	FITTINGS, ETC.		100	LBS
23.	TOTAL WEIGHT		1200	LBS
	VENDOR COST DATA			
24.	MOTOR		1700	USD
25.	MATERIAL COMPONENT COST		2051	USD
26.	SHOP MANPOWER COST		2023	USD
27.	SHOP OVERHEAD		2064	USD
28.	GENERAL OFFICE OVERHEAD		1333	USD
29.	PROFIT		1429	USD
30.	TOTAL COST		10600	USD
31.	RESULTING UNIT COST		8.833	USD/LBS
32.	RESULTING UNIT COST		13.20	USD/GPM
33.	RESULTING UNIT COST		265.0	USD/HP

	MATERIAL USD	MANPOWER USD	MANPOWER MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	10600.	856.	46	0.081
PIPING	12276.	4521.	244	0.368
CIVIL	328.	797.	51	2.427
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	5963.	1466.	76	0.246
ELECTRICAL	427.	697.	35	1.631
INSULATION	0.	0.	0	0.000
PAINT	472.	770.	56	1.632
SUBTOTAL	30066.	9107.	508	0.303

INSTALLED DIRECT COST 39200. INST'L COST/PE RATIO 3.698

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:53:19

```
Equipment Num        :: P-630
Eqipment Name        :: Recycled Water Pump
Associated PFD       :: PFD-P100-A601
Equipment Type       :: CENTRIFUGAL
Equipment Category   :: PUMP
Equipment Description:: 790 gpm, 150 ft head
Number Required      :: 1
Number Spares        :: 1
Scaling Stream       :: 602
Base Cost            :: 10600.00
Cost Basis           :: ICARUS
Cost Year            :: 1997
Base for Scaling     :: 179446.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 2.8000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.7900
Scale Factor Basis   :: GARRETT
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WP630
Utility Type         :: POWER
Date Modified        :: 12/22/98
Notes                :: Expected Power Req. 39 kW.
```

Eq. No.	P-630		
Eq. Name	Recycle Water Pump		
Associated PFD	A601		
Stream for Design	602		
Stream Description	Pump Inlet		
Flow Rate	179446	Kg/hr	R9809G
Average Density	1.00	g/cm^3	R9809G
Frac Solids	0.009		
Flowrate	790.7	gpm	
Outlet Head	150.0	ft	
Estimated Power	52	hp	
	39	kW	
Cost Estimation			
ICARUS- 1997	**$ 9,800**	CS	
	$ 10,600	CI	
	$ 14,300	SS	
Scaling Stream	602		
Scaling Rate	179446		
Scaling Units	Kg/hr		

P-630 CP - 100 P-630

EQUIPMENT ITEM DESIGN DATA SHEET

ANSI

NO.	ITEM	VALUE SPECIFIED BY USER	VALUE USED BY SYSTEM	UNITS
	EQUIPMENT DESIGN DATA			
1.	MATERIAL SYMBOL		CS	
2.	DESIGN TEMPERATURE		120.0	DEG F
3.	DESIGN PRESSURE		150.0	PSIG
4.	HEAD	150.0	150.0	FEET
5.	ASA RATING		150	
6.	DRIVER POWER		40.00	HP
7.	DRIVER SPEED		1800.0	RPM
8.	DRIVER TYPE SYMBOL		MOTOR	
9.	PUMP EFFICIENCY		82.00	PERCENT
	SEAL DATA			
10.	SEAL TYPE		SNGL	
11.	PRIMARY SEAL PIPE PLAN		11	
12.	SEAL PIPING PIPE TYPE		WELD	
13.	SEAL PIPING MATERIAL		A 106	
	PROCESS DESIGN DATA			
14.	CAPACITY	791.0	791.0	GPM
15.	FLUID DENSITY		62.43	PCF
16.	FLUID VISCOSITY		1.000	CPOISE
17.	RESULTING DESIGN VALUE		0.0506	HP/GPM
18.	CAPACITY*HEAD		118650	GPM -FT
	WEIGHT DATA			
19.	PUMP		530	LBS
20.	MOTOR		450	LBS
21.	BASE PLATE		110	LBS
22.	FITTINGS, ETC.		100	LBS
23.	TOTAL WEIGHT		1200	LBS
	VENDOR COST DATA			
24.	MOTOR		1700	USD
25.	MATERIAL COMPONENT COST		2050	USD
26.	SHOP MANPOWER COST		2012	USD
27.	SHOP OVERHEAD		2052	USD
28.	GENERAL OFFICE OVERHEAD		1329	USD
29.	PROFIT		1457	USD
30.	TOTAL COST		10600	USD
31.	RESULTING UNIT COST		8.833	USD/LBS
32.	RESULTING UNIT COST		13.40	USD/GPM
33.	RESULTING UNIT COST		265.0	USD/HP

	MATERIAL USD	MANPOWER USD	MANPOWER MANHOURS	L/M RATIO USD/USD
EQUIPMENT&SETTING	10600.	856.	46	0.081
PIPING	12276.	4521.	244	0.368
CIVIL	328.	797.	51	2.427
STRUCTURAL STEEL	0.	0.	0	0.000
INSTRUMENTATION	5963.	1466.	76	0.246
ELECTRICAL	427.	697.	35	1.631
INSULATION	0.	0.	0	0.000
PAINT	472.	770.	56	1.632
SUBTOTAL	30066.	9107.	508	0.303

INSTALLED DIRECT COST 39200. INST'L COST/PE RATIO 3.698

IPE Version: 4.0
Estimate Base: 1st Quarter 1997 (4.0)
June 30, 1997
Run Date: 16NOV98-11:53:19

```
Equipment Num        :: S-600
Eqipment Name        :: Bar Screen
Associated PFD       :: PFD-P100-A602
Equipment Type       :: SCREEN
Equipment Category   :: SEPARATOR
Equipment Description:: 0.5" Mech. cleaned Screen
Number Required      :: 1
Number Spares        :: 0
Scaling Stream       :: 612
Base Cost            :: 117818.00
Cost Basis           :: CH2MHL91
Cost Year            :: 1991
Base for Scaling     :: 188129.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 1.2000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.3000
Scale Factor Basis   :: ASSUMED
Material of Const    :: CS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WS600
Utility Type         :: POWER
Date Modified        :: 01/13/99
Notes                :: Expected Power Req: .7 kW
```

Eq. No.	S-600		
Eq. Name	Bar Screen		
Associated PFD	A602		
Stream for Design	612		
Stream Description	Eq. Inlet		
Flow Rate (total)	188129	Kg/hr	R9809G
Average Density	0.945		
Liquid Flowrate	876	gpm	
Average Flow	73	gpm	Ch2MHill Report 1991
Cost	$ 55,900		1991
Power Requirement	1	hp	Estimated for Mechanical Cleaners
	0.7	kW	
Cost Estimation			
Scaling Exponent	0.3		Assumed Very Low
Scaled Cost	**$ 117,818**		
Year	1991		
Scaling Stream	612		
Scaling Rate	188129		
Scaling Units	Kg/hr		

Full Fuel Cycle Analysis of Biomass to Ethanol: Wastewater Treatment System Performance

By
CH2M HILL

December 10, 1991

Submitted to
National Renewable Energy Laboratory

CH2M HILL Protected Information

DEN/197R/012.51/1

DESIGN SUMMARY

CASE 3
SOUTHEAST, 2010

S-600

Bar Screens

Number: Two
Type: Mechanically Cleaned
Bar Spacing: 1/2 inch

Equalization Tank

Number: One
Type: Above grade, welded steel
Volume: 225,000 gal
Size: 45 ft diam, 20 ft SWD
Hydraulic Retention Time: 24 hours
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

Primary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Primary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 131 sq ft
Temperature Reduction: 142 degrees F to 131 degrees F
Cooling Water Required: 46.5 gpm

Nutrient Feed System

Number: One
Type: Dry or liquid
Capacity: 7,500 lb/d urea and 3,000 lb triple super phosphate

Anaerobic Reactor

Number: Five
Type: Above grade, welded steel with cover

CASE 3: SOUTHEAST, 2010

		WATER	SOLUBLE SOLIDS	ASH	LIGNIN	CRUDE PROTEIN	XYLOSE	HMF	FURFURAL	GYPSUM (SOL)	GYPSUM (INSOL)	CELLULAS	GLYCEROL	CELL MASS	TOTAL	FLOW gpm
STRM.NO.1	LB/HR	36507	759	191	38	162	139	25	0	81	7	15	847	5	38776	73
PROCESS WATER TO	TSS,mg/l				1043						192				1235	
WASTE TREATMENT	COD,mg/l		51443			7557	4081	1146	0			700	28355	195	93477	
	BOD,mg/l		23326			1778		528	0			165			25797	
	SO4,mg/l									1245	108				1352	
	TDS,mg/l			5241						2223					7464	
STRM.NO.2	LB/HR	43054	0	0	0	0	0	0	3627	0	0	0	0	0	46681	86
OFFGAS FROM	TSS,mg/l				0						0				0	
BLOWDOWN TANK	COD,mg/l		0			0	0	0	140934			0	0	0	140934	
	BOD,mg/l		0			0		0	64981			0			64981	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
WASTE WATER	TSS,mg/l				0						0				0	
FROM CIP/CS	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4	LB/HR	79981	759	181	38	162	139	25	3627	81	7	15	847	5	85867	160
STREAM TO	TSS,mg/l				476						88				564	
ANAEROBIC DIGESTION	COD,mg/l		23481			3449	1863	523	75865			319	12943	89	118532	
	BOD,mg/l		10647			812		241	34980			75			46755	
	SO4,mg/l									568	49				617	
	TDS,mg/l			2267						1015					3282	

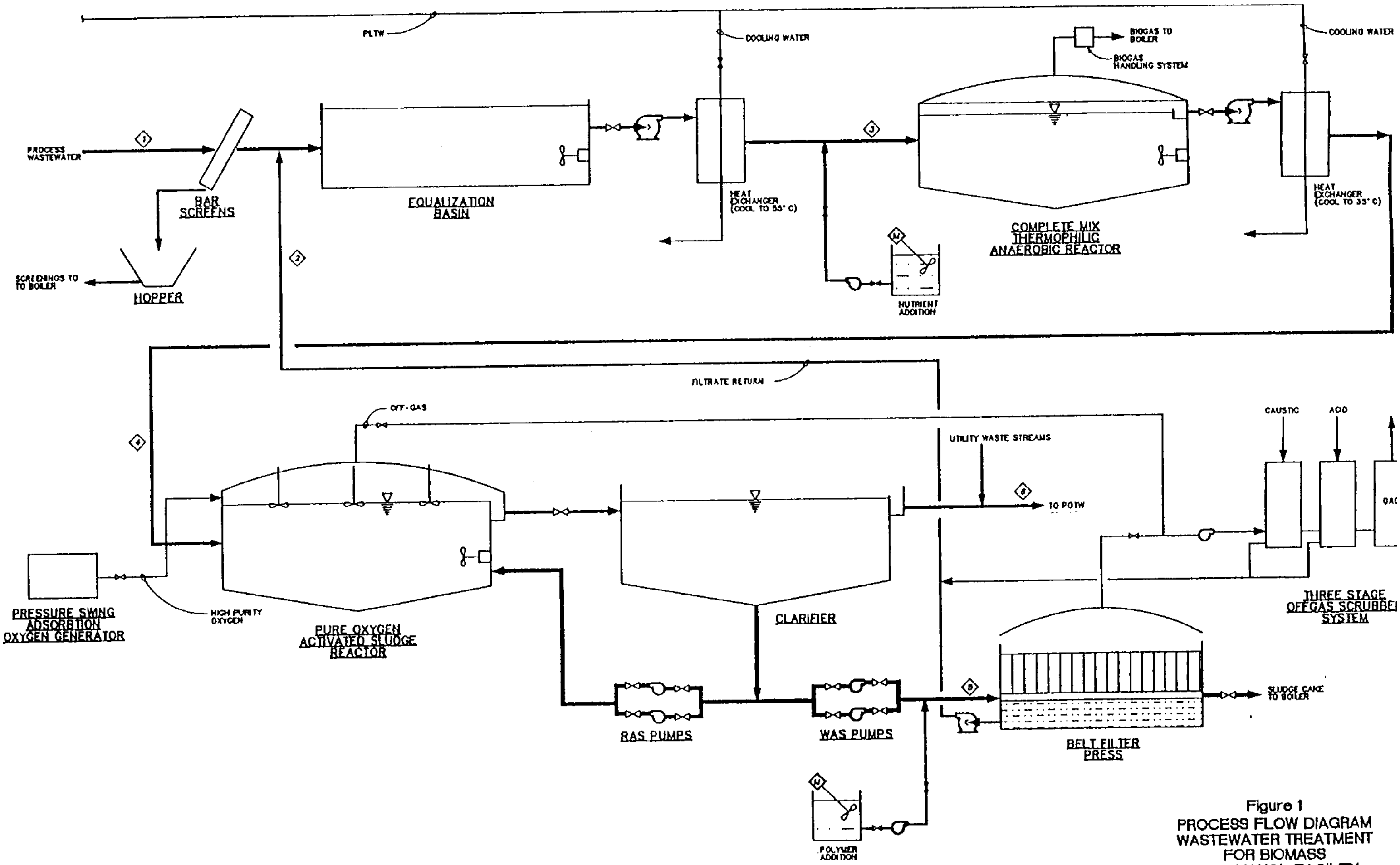


Figure 1
PROCESS FLOW DIAGRAM
WASTEWATER TREATMENT
FOR BIOMASS
TO ETHANOL FACILITY
CASE 6

12/09/91

FILE: GERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN32922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
CASE 3					
GENERAL REQUIREMENTS:					
General Requirements	6.00%		$15,315,257	$918,915	
SITEWORK:					
Clear & Grub	9	ACRES	$2,000.00	$18,000	
Effluent Storage Lagoon (18 Acres):					
Embankment	66,787	CY	$10.00	$667,867	91 MEANS 022-252-0100
HPDE Liner (20 mil)	104,564	SY	$2.50	$261,411	
CLARIFIER STRUCTURE (20'D, 15' SWD):					
Earthwork:					
Excavation	1,068	CY	$3.00	$3,203	
Structural Backfill	23	CY	$10.00	$233	
Backfill	807	CY	$2.00	$1,613	
Concrete:					
12" Slab on Grade	23	CY	$200.00	$4,652	
12" Walls	79	CY	$400.00	$31,633	
Metals:	1	LS	$5,000.00	$5,000	
AERATION TANKS (40'X150'X17'H, ABOVE GRADE):	4	EA			
Concrete:					
12" Slab on Grade	889	CY	$200.00	$177,778	
12" Walls	951	CY	$400.00	$380,593	
Metals:	1	LS	$5,000.00	$5,000	
BUILDINGS:					
Office/Lab	2,100	SF	$100.00	$210,000	
Preliminary Treatment Building	900	SF	$75.00	$67,500	
Pump Building	1,200	SF	$75.00	$90,000	
Belt Filter Press Building	2,000	SF	$75.00	$150,000	
EQUIPMENT			55,900		S-600
Bar Screens	1	EA	$55,900.00	$55,900	
Equalization Tank (Steel,45'D, 20' SWD, 225,000 gal)	1	EA	$126,000.00	$126,000	91 MEANS 132-051-1000 * 1.2
Equalization Tank Mixers (3.2 HP)	3	EA	$9,360.00	$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2	EA	$5,590.00	$11,180	

```
Equipment Num        :: S-601
Eqipment Name        :: Beer Column Bottoms Centrifuge
Associated PFD       :: PFD-P100-A601
Equipment Type       :: CENTRIFUGE
Equipment Category   :: S/L SEPARATOR
Equipment Description:: 36" X 12", 550 HP EACH
Number Required      :: 3
Number Spares        :: 0
Scaling Stream       :: CENTFLOW
Base Cost            :: 659550.00
Cost Basis           :: VENDOR
Cost Year            :: 1998
Base for Scaling     :: 404.000
Base Type            :: FLOW
Base Units           :: GPM
Install. Factor      :: 1.2000
Install. Factor Basis:: DELTA-T98
Scale Factor Exponent:: 0.6000
Scale Factor Basis   :: GARRETT
Material of Const    :: 316SS
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WS601
Utility Type         :: POWER
Date Modified        :: 01/13/99
Notes                :: Expected total Power Req: 993 kW. Number of units
                        and capacity of each unit determined by Aspen.
```

Eq. No.	S-601		
Eq. Name	Beer Columns Bottoms Centrifuge		
Associated PFD	A601		
Stream for Design	525		
Stream Description	Centrifuge Inlet		
Flow Rate (total)	278645	Kg/hr	R9809G
Flow Rate (solids)	31766	Kg/hr	R9809G
Average Density	1.013		
Frac Solids	0.11		
Slurry Flowrate	1211	gpm	
Solids Flowrate	34.9	ton/hr	
Dorr Oliver	**$ 750,000**		
	500	**gpm**	**capacity**
Bird	$ 750,000		
	400	gpm	largest Unit
Power Requirement	550	hp	per 500 gpm, per Merrick attached
Total Power Requirement	1332	hp	
	993	kW	
Use Dorr Oliver			
Number of Units	**3**		
Capacity of Each Unit	404	gpm	
	92882	Kg/hr	
Scaling Factor	**0.60**		
Scaled Cost (Dorr Oliver)	**$ 659,550**		
Scaling Stream	CENTFLOW		
Scaling Rate	404		
Scaling Units	GPM		
Integer Number	**NUMRCENT**		Calculated by ASPEN, max 500 gpm

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FAX

Date: 11/17/98 8:04 AM

To: Bob Wooley
Company:
Fax Number: 303-384-6877
Voice Number:

From: Dick Voiles
Project Number:
Voice Number: 303-751-0741
Number of Sheets:
(including this sheet)

I'm sorry the attached was not in the estimate backup volume. We are putting it in now.

We used the Dorr-Oliver quote for the Beer Col. Btms. Centrifuge. We feel that Bird Machine and Dorr-Oliver are very well established names in centrifugation and that their prices essentially checked each other. Dorr-Oliver had a slightly larger machine - making it a better fit and cheaper.

For the belt filter press (M-614) we used Joe Ruocco's estimate. However we did solicit a price from Compositech to verify Joe. The Compositech stuff is attached.

cc: Jim Kassian
Jim Sharpe
Fran Ferraro

MERRICK ARCHITECTS & ENGINEERS

Merrick & Company
Mail :P.O. Box 22026/ Denver, CO / 80222 / USA
Delivery: 2450 S. Peoria St. / Aurora, CO / 80014
Phone: 303-751-0741 / Fax: 303-751-2581

RECORD OF TELEPHONE CONVERSATION

DATE:	8/21/98	PROJ. NO.: 19013104
FROM:	Ed Sweeny	COMPANY: Dorr-Oliver
LOCATION:		PHONE NO.: 203-838-6120
TO:	Ron Gould	COMPANY: Merrick
LOCATION:		PHONE NO.:

SUBJECT: Beer Column Bottoms Centrifuge

Required ID	36"
Length	12' (4:1)
BHP	400 bowl
	150 scroll
	550 total

316 SS construction

Will need 3 each of 500 gpm model decanters to handle the approximate 1400 gpm total flow.

Cost is $750,000 per machine.

Baker Process

Bird Machine Co. Home Page

Products

Support Services

Contact Information

Contact Information

BAKER HUGHES Baker Pr

Please contact a Bird Machine Company, ~~a Representative~~ or Service Center nearest you or at the headquarters address listed below if you need additional assistance.

BIRD Machine Company, Inc.
100 Neponset Street
South Walpole, MA 02071-9103
Telephone: 508-668-0400 FAX: 508-668-6855

BAKER HUGHES Baker Process

Last modified on:
13 Aug 1998
by Senlin Zhang,
senlin.zhang@bakerhughes.com

Micros Intern Explo
Best expe

FONECON with John Prysi in Torence, CA, at (310) 373-7622, and Ron Gould on 08-25-98:

(1) He is quite familiar with NREL's project. He did some of the equipment work for Amoco's / Stone & Webster's SWAN project, which may have generated process & test data used in this project. He also knows Fran Ferraro.

(2) Their largest centrifuge is a Model #6400:
Capacity = 400 gal/min.
Bowl Diameter = 44"
Bowl Length = 132"
Motor = 300 HP
Mat'l = 316 SS
Centrifugal Force = 1000 G's
Cost = $750,000/each

(3) For 1400 gpm, we will need 4 units; cost = 4 ($750K) = $3,00

(4) If more than 1000 G's are needed (say 2000 G's), then we will have to go to more numbers of smaller units to handle it. This will increase costs, as expected.

5) I also asked about pressure leaving the centrifuge. He said that the liquid stream exits through a series of bottles and gravity feeds into a tank (essentially at atm.). We then would pump liquids out of the tank.

MERRICK ARCHITECTS & ENGINEERS

Merrick & Company
Mail :P.O. Box 22026/ Denver, CO / 80222 / USA
Delivery: 2450 S. Peoria St. / Aurora, CO / 80014
Phone: 303-751-0741 / Fax: 303-751-2581

RECORD OF TELEPHONE CONVERSATION

DATE:	09/10/98	PROJ. NO.:	19013104
FROM:	Roger Schultz	COMPANY:	Ro-Caam
LOCATION:	Denver, CO	PHONE NO.:	(303)470-0770
TO:	Ron Gould	COMPANY:	Merrick Company
LOCATION:	Aurora, CO	PHONE NO.:	(303)751-0741

SUBJECT: NREL Softwood Project - Centrifuge Price Estimate

Roger called to provide pricing information for the beer column bottoms centrifuge for this project (S-601A/B). Based on solids and liquid rates of 40 ton/hr and 1,400 gpm, respectively, he offered the following:

OPTION 1: A single centrifuge, Model #906, good for 1,200 gpm and at a cost of $1,200,000.

OPTION 2: Two (2) centrifuges, Model # 706, each good for 500 to 600 gpm and at a unit cost of $650,000 ($1,300,000 total for two units).

cc: Dick Voiles

```
Equipment Num        :: S-614
Eqipment Name        :: Belt Filter Press
Associated PFD       :: PFD-P100-A603
Equipment Type       :: FILTER-PRESS
Equipment Category   :: S/L SEPARATOR
Equipment Description:: BELT THICKNESS
Number Required      :: 1
Number Spares        :: 0
Scaling Stream       :: AEROBCOO
Base Cost            :: 650223.00
Cost Basis           :: VENDOR
Cost Year            :: 1998
Base for Scaling     :: 438.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 1.8000
Install. Factor Basis:: VENDOR
Scale Factor Exponent:: 0.7200
Scale Factor Basis   :: VENDOR
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WM614
Utility Type         :: POWER
Date Modified        :: 01/13/99
Notes                :: Expected Power Req. 22 kW.
```

Eq. No.	S-614		
Eq. Name	Aerobic Sludge Belt Filter Press		
Associated PFD	A603		
Stream for Design	618		
Stream Description	Reactor Inlet		
Flow Rate	185782	Kg/hr	R9809G
Liquid Density	0.984	g/cc	R9809G
Frac Solids	0		R9809G
Flowrate	831.1	gpm	
Flowrate	1,196,734	gal/day	
Flowrate	188755	L/hr	
COD Concentration	**2323**	**mg/L**	
COD Loading	438	Kg/hr	R9809G (See Conversion below)
COD Concentration	334	mg/L	Phoenix Bio-Systems, Inc. Merrick Appendix F "Case 1",
Flow	766	gpm	
COD Loading	58	Kg/hr	

Cost Estimation	Purchase	Installation	Phoenix Bio-Systems, Inc. Merrick Appendix F "Case 1",
Unit	**$ 110,000**	$ 42,000.00	
Piping	**$ 42,000**	$ 67,000.00	
Totals	**$ 152,000**	$ 109,000.00	

Prorated Additional Piping

Total Cost of Option	$3,737,350	Phoenix Bio-Systems, Inc. Merrick Appendix F "Case 1",
Overhead Portion	$725,000	Design Engineering Fee + Site Preparation
Project Cost Less Overhead	$3,012,350	
Overall Piping & Installation	$371,600	Controls+Temp Control+Piping
Overall Piping & Inst %	12.34%	
Installation Cost Above	$109,000	Per above, extra piping and inst. Prorated
Additional Prorated Installati	$32,197	
Total Installation Cost	**$141,197**	
Installation Factor	**1.93**	

			Phoenix Bio-Systems, Inc. Merrick Appendix
COD Concentration	520	mg/L	F "Case 2",
Flow	1105	gpm	
COD Loading	131	Kg/hr	

			Phoenix Bio-Systems, Inc. Merrick Appendix
Cost Estimation	Purchase	Installation	F "Case 2",
Unit	**$ 210,000**	$ 65,000.00	
	$ 62,000	$ 78,000.00	
Totals	**$ 272,000**	$ 143,000.00	

Prorated Additional Piping

		Phoenix Bio-Systems, Inc. Merrick Appendix
Total Cost of Option	$6,013,805	F "Case 2",
Overhead Portion	$1,165,000	Design Engineering Fee + Site Preparation
Project Cost Less Overhead	$4,848,805	
Overall Piping & Installation	$518,100	Controls+Temp Control+Piping
Overall Piping & Inst %	10.69%	
Installation Cost Above	$143,000	Per above, extra piping and inst. Prorated
Additional Prorated Installati	$44,343	
Total Installation Cost	**$187,343**	
Installation Factor	**1.69**	
Calculated Scaling Factor	0.72	Scaled on COD (related to sludge flow)
Average Installation Fact.	1.8	
Scaled Cost	**$ 650,223**	Scaled on COD
Power Requirement	30 hp	See Compositech Quote Attached
	22.4 kW	
Scaling Stream	**AEROBCOD**	ASPEN Calculated Anerobic Inlet COD
Scaling Rate	**438**	
Scaling Units	**Kg/hr**	

	Kg/hr	COD Kg/hr	Per R9809G
Mass Flow KG/HR			
Glucose	0.00	0	
Xylose	0.00	1.55434E-08	
Unknown	0.00	0	
Colslds	0.00	0	
Ethanol	3.25	6.78210016	
Arabinose	0.00	0	
Galactose	0.00	0	
Mannose	0.00	0	
Glucose Oligomers	0.00	0	
Cellibiose	0.00	0	
Xylose Oligomers	0.00	0	
Mannose Oligomers	0.00	0	
Galactose Oligomers	0.00	0	
Arabinose Oligomers	0.00	0	
Xylitol	0.00	0	
Furfural	54.04	90.2384834	
HMF	18.21	27.6783336	
Methane	2.49	9.95074	
Lactic Acid	0.05	0.056598506	
Acetic Acid	21.11	22.5878391	
Glycerol	0.00	0.000692483	
Succinic Acid	0.00	5.35041E-05	
Denaturant	0.00	0	
Oil	0.00	6.91765E-06	
Acetate Oligomers	0.00	0	
NH4Acet	245.95	281.1238218	
	345.093	438.4186695	Kg/hr of COD

	Kg COD/Kg	
Glucose	1.07	Per Merrick WWT Report 11/98
Xylose	1.07	
Unknown	1.07	
Colslds	0.71	
Ethanol	2.09	
Arabinose	1.07	
Galactose	1.07	
Mannose	1.07	
Glucose Oligomers	1.07	
Cellibiose	1.07	
Xylose Oligomers	1.07	
Mannose Oligomers	1.07	
Gaactose Oligomers	1.07	
Arabinose Oligomers	1.07	
Xylitol	1.22	
Furfural	1.67	
HMF	1.52	
Methane	4	
Lactic Acid	1.07	

Acetic Acid	1.07
Glycerol	1.22
Succinic Acid	0.95
Denaturant	3.52
Oil	2.89
Acetate Oligomers	1.07
NH4Acet	1.143

CLIENT: NREL
PHONE/FAX:
PROJECT NUMBER:
DATE: 5/18/98
TYPE: Anaerobic/Aerobic
LOAD RATE: 12 g/l/d & 0.55 g/l/d
COD: 4,173 mg/l and 334 mg/l
FLOW: 766 gpm

ITEM	Description	Qty	Unit Cost	Installation	Q x UC + I	Totals
Treatability						
Laboratory Analysis						
Preliminary Design						
						$0.00
Equalization						
Dimensions	36'd x 44'h AOS SI St					
Capacity (gal)	330000 gal	1	325,000.00	86,000.00	411,000.00	
						$411,000.00
Main Reactor						
Dimensions	24'd x 60'h AOS	2				
Capacity (gal)	385,000 gal	1	350,000.00	95,000.00	445,000.00	
Distribution Manifold	ICM s/s	8	4,950.00	10,500.00	50,100.00	
Overflow collection system	PVC	2	3,500.00	7,500.00	14,500.00	
Separator	10 x 12 Custom	2	24,500.00	17,500.00	66,500.00	
Sample Cocks	1" PVC	24	50.00	1,200.00	2,400.00	
Packing	TriPack PP	2600	12.00	2,500.00	33,700.00	
Insulation	9000 ft2	9050	7.00		63,350.00	
						$675,550.00
Decarbonator						
Capacity	3,000 gal	1	14,500.00	17,500.00	32,000.00	
Dimensions	6'd x 18'h				0.00	
Distributor	s/s	1	4,850.00	8,700.00	13,550.00	
Packing	TriPack 3.5 PP	400	12.00	1,500.00	6,300.00	
Demister		1	1,500.00	1,000.00	2,500.00	
Gratings	FRP	1	3,500.00	3,000.00	6,500.00	
Fan	3 hp	1	1,250.00	2,200.00	3,450.00	
Drain						
						$64,300.00

Controls						
Field Instruments		1	85,000.00	8,500.00	93,500.00	
Pressure Ind		12	250.00	750.00	3,750.00	
Temp Indicators		12	250.00	750.00	3,750.00	
pH Controller		4	2,500.00	2,000.00	12,000.00	
Biogas Meter		1	4,300.00	1,250.00	5,550.00	
Panel		1	3,800.00	2,250.00	6,050.00	
PLC		1	9,500.00	5,500.00	15,000.00	
Control computer		1	10,500.00	7,500.00	18,000.00	
Software		1	4,000.00	12,000.00	16,000.00	
						$173,600.00
Temp Control						
Hot water heater		0	0.00	0.00	0.00	
Heat Exch		2	6,500.00	14,500.00	27,500.00	
						$27,500.00
BioGas Scrubber						
Capacity	300 cf	1	6,500.00	7,600.00	14,100.00	
Grating	FRP	1	1,800.00	3,350.00	5,150.00	
Media	280	280	7.50	1,550.00	3,650.00	
						$22,900.00
Piping						
PVC		1	75,000.00	55,000.00	130,000.00	
Heat trace/Insulate		1	12,500.00	28,000.00	40,500.00	
						$170,500.00
Macronutrient Tank						
Tank	5000	1	8,500.00	3,500.00	12,000.00	
Nutrient Feed Pump		1	1,500.00	3,800.00	5,300.00	
Micronutrient Tank						
-604 Tank	3000	1	4,500.00	3,500.00	8,000.00	
Nutrient pump		1	1,500.00	3,800.00	5,300.00	
Caustic Tank						
Caustic Dosing Pump	500 gpd	1	1,150.00	3,700.00	4,850.00	
Tank	5500 gal	1	9,500.00	17,500.00	27,000.00	
Iron Tank	200 gal	1	550.00	500.00	1,050.00	
Metering pump		1	850.00	1,550.00	2,400.00	
Phosphate Tank	1000 gal	1	2,500.00	2,500.00	5,000.00	
Metering pump	50 gpd	1	850.00	1,550.00	2,400.00	
						$73,300.00 ✓
			$31,400	41900		

M1.04

Flare						
Burner	**150 CFM**	1	8,500.00	4,000.00	12,500.00	
Auto pilot,N-gas,air		1	4,500.00	3,500.00	8,000.00	
						$20,500.00
System Feed Pump						
Cent	766 gpm, 40' TDH s/s	2	4,900.00	2,700.00	12,500.00	
System Recirc Pump						
Cent	1500 gpm 70' TDH s/s	2	8,000.00	4,500.00	20,500.00	
						$20,500.00
Aerobic Secondary						
Feed Pump	766 gpm 40' TDH s/s	2	4,900.00	3,500.00	13,300.00	
Aerated Lagoon	0.9 mgal	1		500,000.00	500,000.00	
Floating aerators	4x25 hp, 2 x 50 hp	6	25,000.00	22,000.00	172,000.00	
						$685,300.00
Clarifier	180,000 gal	1	155,000.00	115,000.00	270,000.00	
Sludge pumps	2x25hp PD s/s	2	5,500.00	2,900.00	13,900.00	
Effluent pumps/wet wells	2x25hp cent	2	3,500.00	10,500.00	17,500.00	
						$301,400.00
Belt Thickener S 614		1	110,000.00	42,000.00	152,000.00	
,14 **Piping**	Yard	1	42,000.00	67,000.00	109,000.00	
Sludge holding Tanks/Load out		1	~~45,000.00~~	~~25,000.00~~	~~70,000.00~~	
			152,000	109,000 27927		~~$331,000.00~~
Sand Filters						
VortiSand Filters	**0**	**0**	0.00	0.00	136,927 0.00	
Surge Tanks	**0**	**0**	0.00	0.00	0.00	
						$0.00
Chlorinator						
Hypo Storage/feed Tk	0	0	0.00	0.00	0.00	
Metering system		0	0.00	0.00	0.00	
Contact Tank	0	0	0.00	0.00	0.00	
C.T. Aerator	0	0	0.00	0.00	0.00	
						$0.00

Design Engineering Fee	all	1	250,000.00	250,000.00	
Design Drawings					
Shop Drawings					
Wiring Diagrams					
Power Requirements					
Operating Manuals					
Administratative					
					$250,000.00
Site Installation		1		295,000.00	
Site Preparation					
Off-Loading					
Pads					
Power Hook-Up					
Process Hook-Up					
Weather Protection					
Power Outage Protection					
Buildings	Control Building	1		125,000.00	
Fencing					
MCC				55,000.00	
Site Electrical					
Subcontractors					
					$475,000.00
Permits and Fees				35,000.00	
Taxes					
Insurance					
					$35,000.00
TOTAL					**$3,737,350.00**
Plus 12 % Contingency					**$4,185,832.00**

CLIENT: NREL
PHONE/FAX:
PROJECT NUMBER:
DATE: 5/18/98
TYPE: Anaerobic/Aerobic
LOAD RATE: 12 g/l/d & 0.55 g/l/d
COD: 6510 mg/l & 520 mg/l
FLOW: 1105 gpm

ITEM	Description	Qty	Unit Cost	Installation	Q x UC + I	Totals
Treatability						
Laboratory Analysis						
Preliminary Design						
						$0.00
Equalization						
Dimensions						
Capacity (gal)	500,000	1	450,000.00	100,000.00	550,000.00	
						$550,000.00
Main Reactor						
Dimensions	26' d x 60'hAOS aqua St	4				
Capacity (gal) T606	950,000	1	750,000.00	175,000.00	925,000.00	
Distribution Manifold	ICM s/s	16	4,950.00	32,500.00	111,700.00	
06 Overflow collection system	PVC	4	15,500.00	22,000.00	84,000.00	
Separator	10 x 12 FRP Custom	4	28,000.00	38,700.00	150,700.00	
Sample Cocks	1" PVC	36	50.00	1,200.00	3,000.00	
Packing	TriPack PP	6370	12.00	2,500.00	78,940.00	
Insulation		19600	7.00	271,900 EI 159,265 pipe/inst	137,200.00	
			1,218,640	431,165		$1,490,540.00 1649205 135/inst
Decarbonator						
Capacity	5,000 gal	1	22,500.00	27,500.00	50,000.00	
Dimensions	8'd x 18				0.00	
Distributor	s/s	1	7,590.00	9,800.00	17,390.00	
Packing	TriPack 3.5 PP	700	12.00	1,500.00	9,900.00	
Demister		1	2,500.00	1,000.00	3,500.00	
Gratings	FRP	1	4,500.00	3,000.00	7,500.00	
Fan	4 hp	1	1,250.00	2,200.00	3,450.00	
Drain						
			46,740	45,000		$91,740.00

Controls						
Field Instruments		1	85,000.00	8,500.00	93,500.00	
Pressure Ind		18	250.00	750.00	5,250.00	
Temp Indicators		18	250.00	750.00	5,250.00	
pH Controller		6	2,500.00	2,000.00	17,000.00	
Biogas Meter		1	4,300.00	1,250.00	5,550.00	
Panel		1	3,800.00	2,250.00	6,050.00	
PLC		1	9,500.00	5,500.00	15,000.00	
Control computer		1	10,500.00	7,500.00	18,000.00	
Software		1	4,000.00	12,000.00	16,000.00	
						$181,600.00 *
Temp Control						
Hot water heater		0	0.00	0.00	0.00	
Heat Exch		2	12,500.00	12,500.00	37,500.00	
						$37,500.00 *
BioGas Scrubber						
Capacity	800 cf	1	10,800.00	7,800.00	18,600.00	
Grating	FRP	1	2,200.00	4,550.00	6,750.00	
Media	650 CF	750	7.50	1,550.00	7,175.00	
						$32,525.00
Piping						
PVC		1	125,000.00	97,000.00	222,000.00	
Heat trace/Insulate		1	32,000.00	45,000.00	77,000.00	
						$299,000.00 *
Macronutrient Tank						
Tank	5000	1	8,500.00	3,500.00	12,000.00	
Nutrient Feed Pump		1	1,500.00	3,800.00	5,300.00	
Micronutrient Tank						
Tank	3000	1	4,500.00	3,500.00	8,000.00	
Nutrient pump		1	1,500.00	3,800.00	5,300.00	
Caustic Tank						
Caustic Dosing Pump	500 gpd	1	1,150.00	3,700.00	4,850.00	
Tank	5500 gal	1	9,500.00	17,500.00	27,000.00	
Iron Tank	200 gal	1	550.00	500.00	1,050.00	
Metering pump		1	850.00	1,550.00	2,400.00	
Phosphate Tank	1000 gal	1	2,500.00	2,500.00	5,000.00	
Metering pump	50 gpd	1	850.00	1,550.00	2,400.00	
						$73,300.00
			31400	41900		81143
				10% + 7843		
				49743		INST FACT. 2.58

Flare						
Burner	600 CFM	1	10,500.00	4,000.00	14,500.00	
Auto pilot,N-gas,air		1	6,500.00	3,500.00	10,000.00	
						$24,500.00
System Feed Pump						
Cent	1200 gpm, 40' TDH s/s	2	6,500.00	4,600.00	17,600.00	
System Recirc Pump						
Cent	3000 gpm 70' TDH s/s	2	9,500.00	7,500.00	26,500.00	
						$24,500.00
Aerobic Secondary						
Feed Pump	1100 gpm 40' TDH s/s	2	6,500.00	4,200.00	17,200.00	
T-608 Aerated Lagoon T 608	2.5 MM gal	1	100,000.00	750,000.00	850,000.00	
Floating aerators	8 x 50 hp	8	35,000.00	30,000.00	310,000.00	
						$1,177,200.00
Clarifier	275,000 gal	1	225,000.00	125,000.00	350,000.00	
Sludge pumps	2x25hp PD s/s	2	5,500.00	2,900.00	13,900.00	
Effluent pumps/wet wells	2x25hp cent	2	3,500.00	10,500.00	17,500.00	
						$381,400.00
Belt Thickener S 614		1	210,000.00	65,000.00	275,000.00	
614 Piping	Yard	1	62,000.00	78,000.00	140,000.00	
Sludge holding Tanks/Load out		1	~~45,000.00~~	~~25,000.00~~	70,000.00	
			272,000	143000 44405 187405		~~$485,000.00~~
Sand Filters						
VortiSand Filters	0	0	0.00	0.00	0.00	
Surge Tanks	0	0	0.00	0.00	0.00	
						$0.00
Chlorinator						
Hypo Storage/feed Tk	0	0	0.00	0.00	0.00	
Metering system		0	0.00	0.00	0.00	
Contact Tank	0	0	0.00	0.00	0.00	
C.T. Aerator	0	0	0.00	0.00	0.00	
						$0.00

Design Engineering Fee	all	1	475,000.00	475,000.00	
Design Drawings					
Shop Drawings					
Wiring Diagrams					
Power Requirements					
Operating Manuals					
Administratative					
					$475,000.00
Site Installation		1		475,000 00	
Site Preparation					
Off-Loading					
Pads					
Power Hook-Up					
Process Hook-Up					
Weather Protection					
Power Outage Protection					
Buildings	Control Building	1		125,000.00	
Fencing					
MCC				55,000.00	
Site Electrical					
Subcontractors					
					$655,000.00
Permits and Fees				35,000.00	
Taxes					
Insurance					
					$35,000.00
TOTAL					**$6,013,805.00**
Plus 12 % Contingency					**$6,735,461.60**

TOTAL 6,013,805
Less OVHD 4,848,805
PIP & INST 518,100
% of TOTAL 10.7%

COMPOSITECH
P.O.BOX 2673
2404 S. GRAND BLVD. (SUITE 215)
PEARLAND, TEXAS 77581

PHONE: (281) 485-5033
FAX: (281) 485-4594

DATE: August 27, 1998

FROM: JERRY D. PHILEN

ATTN: Andy Siegfried
Merrick

PHONE: 303-751-0741
FAX: 303-368-1299

fax pages (total) 12

I apologize for not being able to spend more time on this for you. This should be helpful, I hope.

If you have any questions, I will be in the office most of the day on Friday !!

Best Regards,

Jerry Philen

M-614

CAPACITY

COMPOSITECH
P.O Box 2673
Pearland , Texas 77581
281-485-5033 / Fax 281-485-4594

Aug. 27,1998
Proposal 98-0826
1

Prepared for

Merrick Engineers & Architects
2450 S.Peoria Street
Aurora, Colorado 80222

Attn: Andy Siegfried

SUBJECT

Project Number : 19013104

Preliminary Budgetary Pricing
for
2.0m Belt Filter Press

Submitted by:

Jerry D. Philen, Vice-President
Compositech, Inc.

COMPOSITECH
P.O Box 2673
Pearland , Texas 77581
281-485-5033 / Fax 281-485-4594

Aug. 27,1998
Proposal 98-0826
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Based on the information supplied, please review the following per our discussions.

Budgetary Proposal

Compositech is pleased to submit this bid for the supply of goods and services for the referenced project : Project # 19013104

Specification Section -- Belt Filter Press

1. **Scope of Supply (CANTILEVER TYPE)**
   A. One (1) 2.0m Belt Filter Press, Compositech Model BPF S7-I consisting of:

   1. Main Structural Frame of ASTM A36 W6X40 beams, Hot Dip Galvanized per ASTM 123 (or equivalent).
   2. All rollers, with the exception of the first pressure roll are constructed of A-519 tubing with a wall thickness of 1/2". Rolls are rubber coated with 1/4" Buna-N, hardness of 85 shore A.
   3. Dodge Bearings/Housing with minimum L 10 life of 100,000 hours. (or equivalent)
   4. Filter belts,endless woven PES, as required for application.
   5. Belt tracking system, proportional pneumatic system
   6. Sprayco/Stamm shower system, 304 SS Header and Shower Box Enclosures.
   7. Chicane blades with lifting mechanism six (6) rows w/ 304ss hardware. **Optional** Distribution Screw substituted depending on density of material.
   8. Belt Drive System. SEW-EURODRIVE gearmotor. mechanical. 5:1 range 30 Hp.
   9. Belt Doctoring assembly with adjustable counter weights.
   10. Belt Tensioning System. pneumatic with 304ss thrust rods and mechanical rack and pinion interlock device.

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Aug. 27,1998
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11. Drip Trays,Pans, Sludge Inlet / Containment system and headbox of 304ss.
12. Gravity support grids, 304ss w/UHMW wear strips
    OPTIONAL: table rolls depending on density of material.
13. Inline Polymer mixing device, 316 ss./ or verticle type mixer.(optional)
14. Local control panel (LCP) Nema 4X FRP or equivalent.
15. Operations and Maintenance Manuals (3).

COMMERCIAL CONDITIONS

1) Price for above items provided under "Scope of Supply.

   A. **ONE (1) 2.0 Meter BPF S7- I . . $ 208,000.00**
      standard / manual operated controls
      (1) optional / complete system control panel . $? ?

   B. ESTIMATED PRICING for items listed below under Services provided by Purchaser (Items 6h) . . $ 65,000.00

2) Pricing is for budgeting only

3) Payment Terms: 35% With Order
   15% With Approved Drawings
   40% Due at Ship Date
   10% Upon Delivery (Net 30 Days) + Freight

4). Delivery: 18 -20 weeks after return of approved drawings.

5) Freight: F.O.B. Houston, Texas

6). **Specifically Excluded Items from the "Scope of Supply" and Materials and Services Provided by Purchaser:**

   a. Local Taxes, Special fees and licenses.
   b. Foundation Construction for any equipment proposed herein
   c. Unloading and uncrating of the proposed equipment.
   d. Installation labor for the proposed equipment .
   e. All connecting piping to the proposed equipment.
   f. All wiring between proposed equipment and control panel.
   g Storage costs associated with the proposed equipment after release from shipment to jobsite.
   h. Polymer feed system, air compressor, washwater booster pump,sludge (slurry) pump, or conveying type equipment.

```
Equipment Num        :: T-602
Eqipment Name        :: Equalization Basin
Associated PFD       :: PFD-P100-A602
Equipment Type       :: FLAT-BTM-STORAGE
Equipment Category   :: TANK
Equipment Description:: 377516 gal, Residence time 7.2 hr,
Number Required      :: 1
Number Spares        :: 0
Scaling Stream       :: 612
Base Cost            :: 350800.00
Cost Basis           :: VENDOR
Cost Year            :: 1998
Base for Scaling     :: 188129.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 1.4200
Install. Factor Basis:: VENDOR
Scale Factor Exponent:: 0.5100
Scale Factor Basis   :: GARRETT
Material of Const    :: CONCRETE
Date Modified        :: 01/13/99
```

Eq. No.	T-602		
Eq. Name	Equalization Basin		
Associated PFD	A602		
Stream for Design	612		
Stream Description	Tank Inlet		
Flow Rate	188129	Kg/hr	R9809G
Average Density	0.945	g/CC	R9809G
Flowrate	876	gpm	
Flowrate	52578	gph	
Residence Time	7.2	hr	Back calculated from Information below
Calculated Volume	377,516	gal	
Volume	330,000	gal	Phoenix Bio-Systems, Inc
Flowrate	766	gpm	Merrick Appendix F "Case 1 - Equalization"
Vendor Equipment Cost	$ 325,000		Per above
Vendor Installation Cost	$ 86,000		
Prorated Additional Piping			
Total Cost of Option	$3,737,350		Phoenix Bio-Systems, Inc. Merrick Appendix F "Case 2",
Overhead Portion	$760,000		Design Engineering Fee + Site Preparation
Project Cost Less Overhead	$2,977,350		
Overall Piping & Installation	$371,600		Controls+Temp Control+Piping
Overall Piping & Inst %	12.48%		
Installation Cost Above	$86,000		Per above, extra piping and inst. Prorated
Additional Prorated Installati	$51,296		
Total Installation Cost	**$137,296**		
Installation Factor	**1.42**		
Scaling Exp	0.51		Garrett
Cost	**$ 350,800**		
Scaling Stream	612		
Scaling Rate	188129		
Scaling Units	Kg/hr		

CLIENT:	**NREL**
PHONE/FAX:	
PROJECT NUMBER:	
DATE:	5/18/98
TYPE:	Anaerobic/Aerobic
LOAD RATE:	12 g/l/d & 0.55 g/l/d
COD:	4,173 mg/l and 334 mg/l
FLOW:	766 gpm

ITEM	Description	Qty	Unit Cost	Installation	Q x UC + I	Totals
Treatability						
Laboratory Analysis						
Preliminary Design						
						$0.00
Equalization						
Dimensions T-602	36'd x 44'h AOS SI St					
12 Capacity (gal)	330000 gal	1	325,000.00	86,000.00	411,000.00	
				51,296 PIP&INST		~~$411,000.00~~
Main Reactor				$137,296		$462296
Dimensions	24'd x 60'h AOS	2				
Capacity (gal)	385,000 gal	1	350,000.00	95,000.00	445,000.00	
Distribution Manifold	ICM s/s	8	4,950.00	10,500.00	50,100.00	
Overflow collection system	PVC	2	3,500.00	7,500.00	14,500.00	
Separator	10 x 12 Custom	2	24,500.00	17,500.00	66,500.00	
Sample Cocks	1" PVC	24	50.00	1,200.00	2,400.00	
Packing	TriPack PP	2600	12.00	2,500.00	33,700.00	
Insulation	9000 ft2	9050	7.00		63,350.00	
						$675,550.00
Decarbonator						
Capacity	3,000 gal	1	14,500.00	17,500.00	32,000.00	
Dimensions	6'd x 18'h				0.00	
Distributor	s/s	1	4,850.00	8,700.00	13,550.00	
Packing	TriPack 3.5 PP	400	12.00	1,500.00	6,300.00	
Demister		1	1,500.00	1,000.00	2,500.00	
Gratings	FRP	1	3,500.00	3,000.00	6,500.00	
Fan	3 hp	1	1,250.00	2,200.00	3,450.00	
Drain						
						$64,300.00

Controls						
Field Instruments		1	85,000.00	8,500.00	93,500.00	
Pressure Ind		12	250.00	750.00	3,750.00	
Temp Indicators		12	250.00	750.00	3,750.00	
pH Controller		4	2,500.00	2,000.00	12,000.00	
Biogas Meter		1	4,300.00	1,250.00	5,550.00	
Panel		1	3,800.00	2,250.00	6,050.00	
PLC		1	9,500.00	5,500.00	15,000.00	
Control computer		1	10,500.00	7,500.00	18,000.00	
Software		1	4,000.00	12,000.00	16,000.00	
						$173,600.00 *
Temp Control						
Hot water heater		0	0.00	0.00	0.00	
Heat Exch		2	6,500.00	14,500.00	27,500.00	
						$27,500.00 *
BioGas Scrubber						
Capacity	300 cf	1	6,500.00	7,600.00	14,100.00	
Grating	FRP	1	1,800.00	3,350.00	5,150.00	
Media	280	280	7.50	1,550.00	3,650.00	
						$22,900.00
Piping						
PVC		1	75,000.00	55,000.00	130,000.00	
Heat trace/Insulate		1	12,500.00	28,000.00	40,500.00	
						$170,500.00 *
Macronutrient Tank						
Tank	5000	1	8,500.00	3,500.00	12,000.00	
Nutrient Feed Pump		1	1,500.00	3,800.00	5,300.00	
Micronutrient Tank	M604		10			
04 Tank	3000	1	4,500.00	3,500.00	8,000.00	
Nutrient pump		1	1,500.00	3,800.00	5,300.00	
Caustic Tank			6			
Caustic Dosing Pump	500 gpd	1	1,150.00	3,700.00	4,850.00	
Tank	5500 gal	1	9,500.00	17,500.00	27,000.00	
Iron Tank	200 gal	1	550.00	500.00	1,050.00	
Metering pump		1	850.00	1,550.00	2,400.00	
Phosphate Tank	1000 gal	1	2,500.00	2,500.00	5,000.00	
Metering pump	50 gpd	1	850.00	1,550.00	2,400.00	
						$73,300.00
			$31,400			

Flare						
Burner	150 CFM	1	8,500.00	4,000.00	12,500.00	
Auto pilot,N-gas,air		1	4,500.00	3,500.00	8,000.00	
						$20,500.00
System Feed Pump						
Cent	766 gpm, 40' TDH s/s	2	4,900.00	2,700.00	12,500.00	
System Recirc Pump						
Cent	1500 gpm 70' TDH s/s	2	8,000.00	4,500.00	20,500.00	
						$20,500.00
Aerobic Secondary						
Feed Pump	766 gpm 40' TDH s/s	2	4,900.00	3,500.00	13,300.00	
Aerated Lagoon	0.9 mgal	1		500,000.00	500,000.00	
Floating aerators	4x25 hp, 2 x 50 hp	6	25,000.00	22,000.00	172,000.00	
						$685,300.00
Clarifier	180,000 gal	1	155,000.00	115,000.00	270,000.00	
Sludge pumps	2x25hp PD s/s	2	5,500.00	2,900.00	13,900.00	
Effluent pumps/wet wells	2x25hp cent	2	3,500.00	10,500.00	17,500.00	
						$301,400.00
Belt Thickener		1	110,000.00	42,000.00	152,000.00	
Piping	Yard	1	42,000.00	67,000.00	109,000.00	
Sludge holding Tanks/Load out		1	45,000.00	25,000.00	70,000.00	
						$331,000.00
Sand Filters						
VortiSand Filters	0	0	0.00	0.00	0.00	
Surge Tanks	0	0	0.00	0.00	0.00	
						$0.00
Chlorinator						
Hypo Storage/feed Tk	0	0	0.00	0.00	0.00	
Metering system		0	0.00	0.00	0.00	
Contact Tank	0	0	0.00	0.00	0.00	
C.T. Aerator	0	0	0.00	0.00	0.00	
						$0.00

Design Engineering Fee	all	1	250,000.00	250,000.00	
Design Drawings					
Shop Drawings					
Wiring Diagrams					
Power Requirements					
Operating Manuals					
Administratative					
					$250,000.00 +
Site Installation		1		295,000.00	
Site Preparation					
Off-Loading					
Pads					
Power Hook-Up					
Process Hook-Up					
Weather Protection					
Power Outage Protection					
Buildings	Control Building	1		125,000.00	
Fencing					
MCC				55,000.00	
Site Electrical					
Subcontractors					
					$475,000.00 +
Permits and Fees				35,000.00	
Taxes					
Insurance					
					$35,000.00 +
TOTAL					$3,737,350.00
Plus 12 % Contingency					$4,185,832.00

TOTAL 3,737,350
Less OVHD # 760,000
SUB 2,977,350
PIP & INST * 371600
PIP& INST % SUB 12.5%

```
Equipment Num        :: T-606
Eqipment Name        :: Anaerobic Digestor
Associated PFD       :: PFD-P100-A602
Equipment Type       :: FLAT-BTM-STORAGE
Equipment Category   :: TANK
Equipment Description:: 810250 gal each, space velocity 12g COD/L/DAY
Number Required      :: 4
Number Spares        :: 0
Scaling Stream       :: ANEROVOL
Base Cost            :: 881081.00
Cost Basis           :: VENDOR
Cost Year            :: 1998
Base for Scaling     :: 810250.000
Base Type            :: SIZE
Base Units           :: GAL
Install. Factor      :: 1.0400
Install. Factor Basis:: VENDOR
Scale Factor Exponent:: 0.5100
Scale Factor Basis   :: GARRETT
Material of Const    :: EPOXY-LINED
Date Modified        :: 01/13/99
Notes                :: Total volume calculated by Aspen.  Number of
                        vessels determined using 950,000 gal as max per
                        vessel.  Actual volumn per vessel determined by
                        total volume/integer num of vessels
```

Eq. No.	T-606		
Eq. Name	Anerobic Digestor		
Associated PFD	A602		
Stream for Design	613		
Stream Description	Reactor Inlet		
Flow Rate	188129	Kg/hr	R9809G
Liquid Density	0.985	g/cc	R9809G
Frac Solids	0		R9809G
Flowrate	840.7	gpm	
Flowrate	50442.6	gph	
Flowrate	190945.9	L/hr	
COD Concentration	**32122.9**	**mg/L**	
COD Loading	6133.7	Kg/hr	R9809G (See Conversion below)
COD Loading	147209698	g/day	
Space Velocity	12.0	g/L/day	Merrick WWT Report 11/98
Volume	12267474.8	L	
Volume	**3,241,000**	**gal**	
Cost Estimation 1			
Volume	950,000	gal	Merrick Appendix F "Case 2 - Main Reactor"
	Purchase	Installation	Phoenix Bio-Systems, Inc
Vessel Cost	**$750,000**	**$175,000**	
Distribution Manifold	**$79,200**	**$32,500**	
Overflow collection	**$62,000**	**$22,000**	
Separator	**$112,000**	**$38,700**	
Sample Cocks	**$1,800**	**$1,200**	
Packing	**$76,440**	**$2,500**	
Insulation	**$137,200**		
Total	**$1,218,640**	**$271,900**	
Prorated Additional Piping			
Total Cost of Option	$6,013,805		Phoenix Bio-Systems, Inc. Merrick Appendix F "Case 2",
Overhead Portion	$1,165,000		Design Engineering Fee + Site Preparation
Project Cost Less Overhead	$4,848,805		
Overall Piping & Installation	$518,100		Controls+Temp Control+Piping
Overall Piping & Inst %	10.69%		
Installation Cost Above	$271,900		Per above, extra piping and inst. Prorated
Additional Prorated Installati	$159,266		
Installation Cost	$431,166		Per above, extra piping and inst. Prorated
Installation Factor	**1.35**		
Number of Vessels	4		Round up to the nearest integer based on 950000 gal max
Volume of Each Vessel	810,250		Calculate volume based on integer number of vessels and the volume requirement.
Scaling Exponent	0.51		Garrett
Scaled Cost per Vessel	$ 1,123,653		
Total Cost	**$ 4,494,611**		4 Vessels

Cost Estimation 2			
Vessel Cost	$	493,391	Chattanogga Quote
Volume		962,651 gal	
Other Equipment	$	468,640	Merrick Appendix F "Case 2 - Main Reactor"
Total Cost	$	962,031	
Number of Vessels		4	Round up to the nearest integer based on 950000 gal max
Volume of Each Vessel		810,250	Calculate volume based on integer number of vessels and the volume requirement.
Scaling Exponent		0.51	Garrett
Scaled Cost per Vessel	$	881,081	
Total Cost	**$**	**3,524,323**	4 Vessels
Installation on Vessel		0	Field Errection Costs Included
Installation of Other Equipm	$	157,412	Installation Costs Listed in Merrick + 10.7% proation of Piping and Inst.
Installation Factor		**1.04**	

Scaling Stream	**ANEROVOL**	Total volume required per vessel, calculated by ASPEN
Scaling Rate	**810250**	
Scaling Units	**gal**	
Integer Number Required	**INUMANER**	Integer Number of Vessels calculated by ASPEN, based on max volume of 950,000 gal per vessel

Mass Flow KG/HR	Kg/hr	COD Kg/hr	Per R9809G
Glucose	0.000	0	
Xylose	0.000	2.2205E-07	
Unknown	0.000	0	
Colslds	0.000	0	
Ethanol	46.858	97.9330319	
Arabinose	0.000	9.3396E-09	
Galactose	0.000	0	
Mannose	0.000	0	
Glucose Oligomers	0.000	0	
Cellibiose	0.000	0	
Xylose Oligomers	0.000	1.3258E-08	
Mannose Oligomers	0.000	0	
Galactose Oligomers	0.000	0	
Arabinose Oligomers	0.000	5.3941E-10	
Xylitol	0.000	0	
Furfural	777.247	1298.00182	
HMF	261.927	398.128736	
Methane	0.000	0	
Lactic Acid	0.756	0.80855053	
Acetic Acid	301.690	322.808621	
Glycerol	0.001	0.00069248	
Succinic Acid	0.001	0.00076434	
Denaturant	0.000	0	

Oil	0.000	9.8824E-05	
Acetate Oligomers	0.000	0	
NH4Acet	3513.609	4016.05509	
		6133.7374	Kg/hr of COD

	Kg COD/Kg	
Glucose	1.07	Per Merrick WWT Report 11/98
Xylose	1.07	
Unknown	1.07	
Colslds	0.71	
Ethanol	2.09	
Arabinose	1.07	
Galactose	1.07	
Mannose	1.07	
Glucose Oligomers	1.07	
Cellibiose	1.07	
Xylose Oligomers	1.07	
Mannose Oligomers	1.07	
Gaactose Oligomers	1.07	
Arabinose Oligomers	1.07	
Xylitol	1.22	
Furfural	1.67	
HMF	1.52	
Methane	4	
Lactic Acid	1.07	
Acetic Acid	1.07	
Glycerol	1.22	
Succinic Acid	0.95	
Denaturant	3.52	
Oil	2.89	
Acetate Oligomers	1.07	
NH4Acet	1.143	

Wooley, Robert

From: Dick.Voiles@merrick.com
Sent: Tuesday, November 17, 1998 4:45 PM
To: robert_wooley@nrel.gov; Fran.Ferraro@merrick.com; Jim.Sharpe@merrick.com; James.Kassian@merrick.com; Dick.Voiles@merrick.com
Subject: Anaerobic digester reactor materials

Joe Ruocco says the reactors for all cases will be AO Smith, bolt-together, epoxy lined, carbon steel. These tanks are "cheap, easy and quick" and they are technically good for the service.

Piping can be schedule 80 PVC.

The separator which is an internal is FRP.

Agitator shaft/blades are stainless.

CLIENT:	NREL
PHONE/FAX:	
PROJECT NUMBER:	
DATE:	5/18/98
TYPE:	Anaerobic/Aerobic
LOAD RATE:	12 g/l/d & 0.55 g/l/d
COD:	6510 mg/l & 520 mg/l
FLOW:	1105 gpm

ITEM	Description	Qty	Unit Cost	Installation	Q x UC + I	Totals
Treatability						
Laboratory Analysis						
Preliminary Design						$0.00
Equalization						
Dimensions						
Capacity (gal)	500,000	1	450,000.00	100,000.00	550,000.00	$550,000.00
Main Reactor						
Dimensions	26' d x 60'hAOS aqua St	4				
Capacity (gal)	950,000	1	750,000.00	175,000.00	925,000.00	
Distribution Manifold	ICM s/s	16	4,950.00	32,500.00	111,700.00	
.606 Overflow collection system	PVC	4	15,500.00	22,000.00	84,000.00	
Separator T606	10 x 12 FRP Custom	4	28,000.00	38,700.00	150,700.00	
Sample Cocks	1" PVC	36	50.00	1,200.00	3,000.00	
Packing	TriPack PP	6370	12.00	2,500.00	78,940.00	
Insulation		19600	7.00		137,200.00	
			1,218,640	271,900 E 159,265 pipe inst 431,165		$1,490,540.00 1649305 (35 INST
Decarbonator						
Capacity	5,000 gal	1	22,500.00	27,500.00	50,000.00	
Dimensions	8'd x 18				0.00	
Distributor	s/s	1	7,590.00	9,800.00	17,390.00	
Packing	TriPack 3.5 PP	700	12.00	1,500.00	9,900.00	
Demister		1	2,500.00	1,000.00	3,500.00	
Gratings	FRP	1	4,500.00	3,000.00	7,500.00	
Fan	4 hp	1	1,250.00	2,200.00	3,450.00	
Drain						
			46,740	45,000		$91,740.00

Controls						
Field Instruments		1	85,000 00	8,500.00	93,500.00	
Pressure Ind		18	250.00	750.00	5,250.00	
Temp Indicators		18	250.00	750.00	5,250.00	
pH Controller		6	2,500.00	2,000.00	17,000.00	
Biogas Meter		1	4,300.00	1,250.00	5,550.00	
Panel		1	3,800.00	2,250.00	6,050.00	
PLC		1	9,500.00	5,500.00	15,000.00	
Control computer		1	10,500.00	7,500.00	18,000.00	
Software		1	4,000.00	12,000.00	16,000.00	
						$181,600.00*
Temp Control						
Hot water heater		0	0.00	0.00	0 00	
Heat Exch		2	12,500.00	12,500.00	37,500.00	
						$37,500.00*
BioGas Scrubber						
Capacity	800 cf	1	10,800.00	7,800.00	18,600.00	
Grating	FRP	1	2,200.00	4,550.00	6,750.00	
Media	650 CF	750	7.50	1,550.00	7,175.00	
						$32,525.00
Piping						
PVC		1	125,000.00	97,000.00	222,000.00	
Heat trace/Insulate		1	32,000.00	45,000.00	77,000.00	
						$299,000.00 *
Macronutrient Tank						
Tank	5000	1	8,500.00	3,500.00	12,000.00	
Nutrient Feed Pump		1	1,500.00	3,800.00	5,300.00	
Micronutrient Tank						
Tank	3000	1	4,500.00	3,500.00	8,000.00	
Nutrient pump		1	1,500.00	3,800.00	5,300.00	
Caustic Tank						
Caustic Dosing Pump	500 gpd	1	1,150.00	3,700.00	4,850.00	
Tank	5500 gal	1	9,500.00	17,500.00	27,000.00	
Iron Tank	200 gal	1	550.00	500 00	1,050.00	
Metering pump		1	850.00	1,550.00	2,400.00	
Phosphate Tank	1000 gal	1	2,500.00	2,500.00	5,000.00	
Metering pump	50 gpd	1	850.00	1,550.00	2,400.00	
						$73,300.00

Flare						
Burner	600 CFM	1	10,500.00	4,000.00	14,500.00	
Auto pilot,N-gas,air		1	6,500.00	3,500.00	10,000.00	
						$24,500.00
System Feed Pump						
Cent	1200 gpm, 40' TDH s/s	2	6,500.00	4,600.00	17,600.00	
System Recirc Pump						
Cent	3000 gpm 70' TDH s/s	2	9,500.00	7,500.00	26,500.00	
						$24,500.00
Aerobic Secondary						
Feed Pump	1100 gpm 40' TDH s/s	2	6,500.00	4,200.00	17,200.00	
T-608 Aerated Lagoon T 608	2.5 MM gal	1	100,000.00	750,000.00	850,000.00	
Floating aerators	8 x 50 hp	8	35,000.00	30,000.00	310,000.00	
						$1,177,200.00
Clarifier	275,000 gal	1	225,000.00	125,000.00	350,000.00	
Sludge pumps	2x25hp PD s/s	2	5,500.00	2,900.00	13,900.00	
Effluent pumps/wet wells	2x25hp cent	2	3,500.00	10,500.00	17,500.00	
						$381,400.00
Belt Thickener		1	210,000.00	65,000.00	275,000.00	
Piping	Yard	1	62,000.00	78,000.00	140,000.00	
Sludge holding Tanks/Load out		1	45,000.00	25,000.00	70,000.00	
						$485,000.00
Sand Filters						
VortiSand Filters	0	0	0.00	0.00	0.00	
Surge Tanks	0	0	0.00	0.00	0.00	
						$0.00
Chlorinator						
Hypo Storage/feed Tk	0	0	0.00	0.00	0.00	
Metering system		0	0.00	0.00	0.00	
Contact Tank	0	0	0.00	0.00	0.00	
C.T. Aerator	0	0	0.00	0.00	0.00	
						$0.00

Design Engineering Fee	all	1	475,000.00	475,000.00	
Design Drawings					
Shop Drawings					
Wiring Diagrams					
Power Requirements					
Operating Manuals					
Administratative					$475,000.00 +
Site Installation		1		475,000.00	
Site Preparation					
Off-Loading					
Pads					
Power Hook-Up					
Process Hook-Up					
Weather Protection					
Power Outage Protection					
Buildings	Control Building	1		125,000.00	
Fencing					
MCC				55,000.00	
Site Electrical					
Subcontractors					$655,000.00 +
Permits and Fees				35,000.00	
Taxes					
Insurance					$35,000.00 +
TOTAL					$6,013,805.00
Plus 12 % Contingency					$6,735,461.60

TOTAL 6,013,805
Loss OVHD 4,848,805
PIP & INST 518,100
% OF TOTAL 10.7%

CHATTANOOG
BOILER AND TANK C

PHONE CA

FOR Hank DATE 4/27 TIME 5:00
M Jason Riddell
OF Chatanooga Boiler Tank
PHONE (423) 755-6718 (FAX / MOBILE; AREA CODE, NUMBER, EXTENSION)
MESSAGE RE: Quote - if don't talk to him today, you can talk to Joe Giada at (423) 266-7118
JM
SIGNED

PHON | X RETURN YOUR C | PLEASE | WILL C AGAI | CAME SEE Y | WANTS SEE Y

Tops FORM 40

March 25, 1998

Delta-T
460 McLaws Circle, Suite 150
Williamsburg, VA 23185

Attention: Mr. Hank Majdeski

Reference: DF-068
CB&T Est. 98-069

Dear Sir:

I am pleased to quote a budget price to furnish the necessary material and labor to design, detail, fabricate, erect, and test thirty-seven (37) field tanks as per the attached sketches and the provided specifications, as follows:

T-301 (VALVE/10)

1) Budget pricing is quoted as:

	Qty	Minnesota	North Carolina
F-300A/W	23	$11,348,000	$10,796,000
F-306A/B	2	$ 621,000	$ 598,000
F-400A/L	10	~~$ 1,733,000~~	$ 1,639,000
F-404A/B (2.5 psig)	2	$ 201,000	$ 190,000
F-404A/B (15 psig)	2	$ 317,000	$ 298,000

2) Estimated net empty weight and field labor MH per tank are:

	Qty	Weight (tons)	Field MH
F-300 A/W	23	2913	40,000
F-306A/B	2	147	2,700
F-400A/L	10	334	8,300
F-404A/B (2.5 psig)	2	30	1,100
F-404 A/B (15 psig)	2	61	1,600

3) Estimated pricing is inclusive of all sales and use taxes, please advise if project is non-taxable.

4) Tanks will be designed per API-650 with the exception of F-404A/B (15 psig) which will be designed in accordance with ASME Sect. VIII.

CHATTANOOGA
BOILER AND TANK CO.
1011 E. MAIN STREET (423) 266-711
P.O. BOX 110 / CHATTANOOGA, TN 37401 \ FAX (423) 755-670

Thank you for the opportunity to provide this estimate. Please contact me if you require any additional information or a firm bid and subsequent construction schedule is needed.

Sincerely,

Jason Riddell
Project Manager

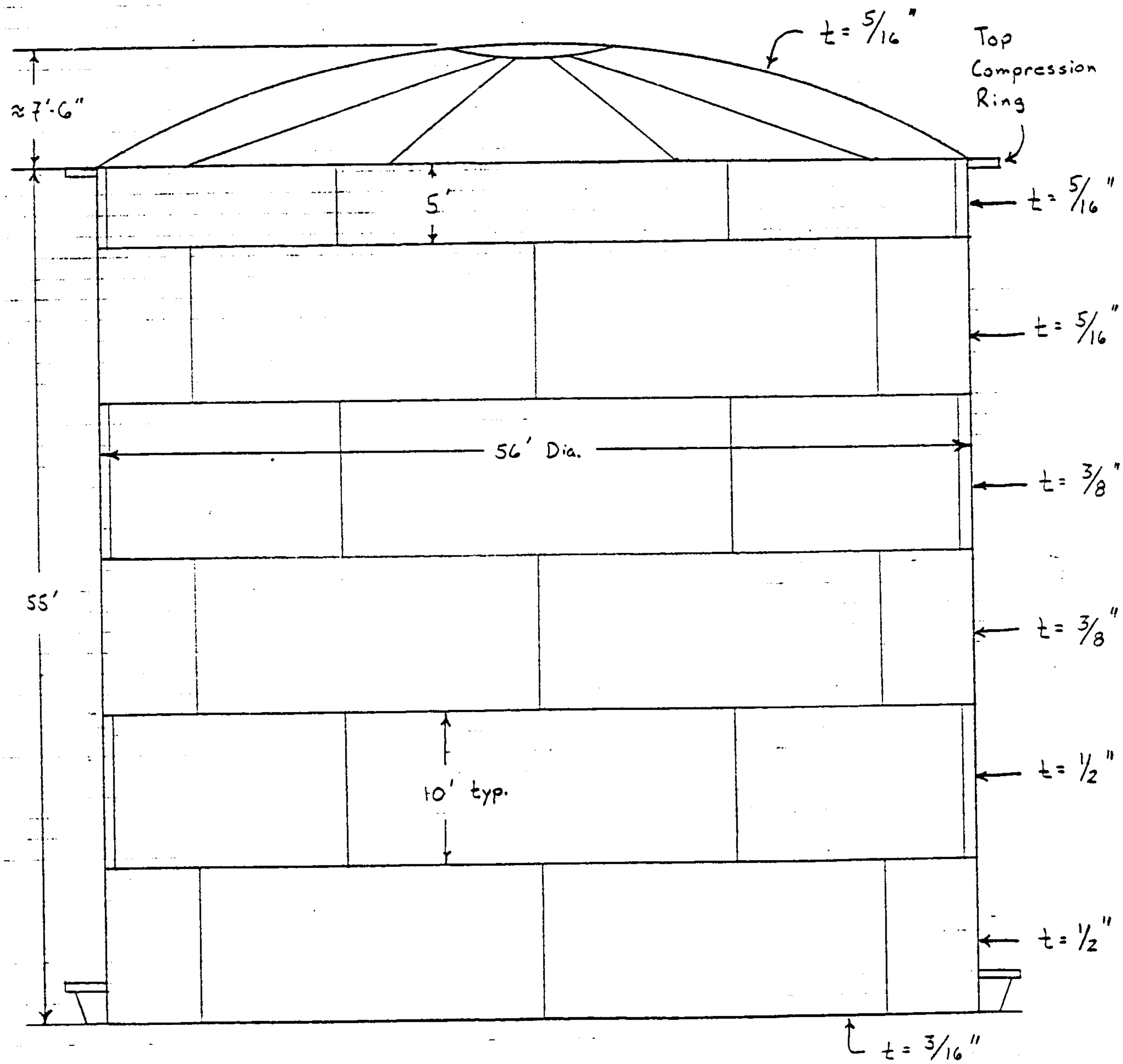
2

CBI MANUFACTURING CO., INC.

P.O. BOX 11566 CHATTANOOGA, TN 37401

CUSTOMER Delta - T	JOB NO. Est # 98-069
PROJECT	
ITEM F-300 A/W	PAGE 1 OF 5

Roof + Bottom : Lap Weld - Top Side Only



REVISION	
BY/DATE	JR 3-24-98
CHKD/DATE	

3

Summarized Field Fabricted Tank Specification

Preliminary

Item	Quantity	Description	Diameter, Ft	Height, FT	Working vol, Gal Ea	Materials	Fluid Type	Fluid Specific Gravity	Design Pressure PSIG	De Tem
1	23	F-300A/W	56	55	962,651	304L	Slurry, 8 wgt % SS, 4 wgt % DS	1.06	2.5	-4
2	2	F-306A/B	49	48	643,226	304L	Slurry, 8 wgt % SS, 12 wgt % DS	1.06	2.5	-4
3	10	F-400A/L	36	37	267,631	304L	Slurry, 5 wgt % SS, 1 wgt % DS	1.06	2.5	-45
4	2	F-404A/B	24	24	77,155	304L	Slurry, 2 wgt % SS, 1 wgt % DS	1.01	15.0	-45
5	2	F-404A/B	24	24	77,155	304L	Slurry, 2 wgt % SS, 1 wgt % DS	1.01	2.5	-45

Notes
1) Tanks to be designed to API-650 or supplier recommended equal suitable for ethanol plant purposes
2) Budget pricing needed for union & non-union basis
3) Require estimated field direct labor MH for installation of each item for each unit
4) Assume union location in Minnesota....Non-union location in North Carolina
5) Provided estimated net empty weight for each item
6) Pricing and manhour estimates should be current day basis

Nozzle Schedule (Each Tank)

24" Manway	20" Hatch	3" Level Connectio n	12" Process Inlet	12' Process Outlet	20" Vent	12" Agitiator	6" Sparger	8" CIP	6" Steam	3/4" Thermow el	1" Le Swi
1	1	2	1	1	1	3	6	2	1	2	1
1	1	2	1	1	1	3	6	2	1	2	1
1	1	2	1	1	1	2	6	2	1	2	1
1	1	2	1	1	1	1	6	2	1	2	1
1	1	2	1	1	1	1	6	2	1	2	1

8

```
Equipment Num        :: T-608
Eqipment Name        :: Aerobic Digestor
Associated PFD       :: PFD-P100-A603
Equipment Type       :: LINED-PIT
Equipment Category   :: REACTOR
Equipment Description:: 19500000 gal, 16.3 day residence time
Number Required      :: 1
Number Spares        :: 0
Scaling Stream       :: AEROBVOL
Base Cost            :: 635173.00
Cost Basis           :: MERRICK98
Cost Year            :: 1998
Base for Scaling     :: 19506756.000
Base Type            :: SIZE
Base Units           :: GAL
Install. Factor      :: 1.0000
Install. Factor Basis:: MERRICK98
Scale Factor Exponent:: 1.0000
Material of Const    :: POLYMER LINED
Date Modified        :: 01/13/99
Notes                :: Using Goble Sampson 16.3 day residence time
```

Eq. No.	T-608		
Eq. Name	Aerobic Digestor		
Associated PFD	A603		

Stream for Design	618			
Stream Description	Reactor Inlet			
Flow Rate	185782	Kg/hr	R9809G	
Liquid Density	0.984	g/cc	R9809G	
Frac Solids	0		R9809G	
Flowrate	831.1	gpm		1196733.523
Flowrate	1,196,734	gal/day		
Flowrate	188755.4	L/hr		
COD Concentration	**2323**	**mg/L**		

Sizing Option 1			Phoenix Bio-Systems, Inc, Merrick Report
COD Loading	438.4	Kg/hr	R9809G (See Conversion below)
COD Loading	10,522,048	g/day	
Space Velocity	0.55	g/L/day	Merrick WWT Report 11/98
Volume	19,130,996	L	
Volume	**5,054,000**	**gal**	

Sizing Option 2			Goble Sampson, Merrick Report
Residence Time	16.3	days	
Volume	**19,506,756**	**gal**	

Cost Estimation

Vessel Cost	**$504,700**		Merrick Base
Volume	**15,499,818**	gal	
Installation Cost	$0		Field Errected
Installation Factor	**1.00**		
Scaling Exponent	1.00		Garrett

Scaled Cost Option 1	**$ 164,567**	Size probably not reasonable
Scaled Cost Option 2	**$ 635,173**	

Scaling Stream	**AEROBVOL**	Total volume required per vessel, calculated by ASPEN
Scaling Rate	**17,951,003**	
Scaling Units	**gal**	

	Kg/hr	COD Kg/hr	Per R9809G
Mass Flow KG/HR			
Glucose	0.00	0	
Xylose	0.00	1.5543E-08	
Unknown	0.00	0	
Colslds	0.00	0	
Ethanol	3.25	6.78210016	
Arabinose	0.00	0	
Galactose	0.00	0	
Mannose	0.00	0	
Glucose Oligomers	0.00	0	

Cellibiose	0.00	0	
Xylose Oligomers	0.00	0	
Mannose Oligomers	0.00	0	
Galactose Oligomers	0.00	0	
Arabinose Oligomers	0.00	0	
Xylitol	0.00	0	
Furfural	54.04	90.2384834	
HMF	18.21	27.6783336	
Methane	2.49	9.95074	
Lactic Acid	0.05	0.05659851	
Acetic Acid	21.11	22.5878391	
Glycerol	0.00	0.00069248	
Succinic Acid	0.00	5.3504E-05	
Denaturant	0.00	0	
Oil	0.00	6.9176E-06	
Acetate Oligomers	0.00	0	
NH4Acet	245.95	281.123822	
	345.093	438.418669	Kg/hr of COD

	Kg COD/Kg	
Glucose	1.07	Per Merrick WWT Report 11/98
Xylose	1.07	
Unknown	1.07	
Colslds	0.71	
Ethanol	2.09	
Arabinose	1.07	
Galactose	1.07	
Mannose	1.07	
Glucose Oligomers	1.07	
Cellibiose	1.07	
Xylose Oligomers	1.07	
Mannose Oligomers	1.07	
Gaactose Oligomers	1.07	
Arabinose Oligomers	1.07	
Xylitol	1.22	
Furfural	1.67	
HMF	1.52	
Methane	4	
Lactic Acid	1.07	
Acetic Acid	1.07	
Glycerol	1.22	
Succinic Acid	0.95	
Denaturant	3.52	
Oil	2.89	
Acetate Oligomers	1.07	
NH4Acet	1.143	

AERATOR SIZING CALCULATIONS FOR:

National Renewable Energy Lab

Date: 11/20/98

Goble Sampson
Aeration Lagoon
Size

Design Criteria

To convert from mg/l to lbs/day use the following equation:
mg/l x 8.34 lb / 1,000,000 x Daily flow (MGD)

Flow :	1.17	Million Gallons per Day			
BOD demand :	1660	mg/l	converts to:	16198	lbs/day
Total Sus Solids:	200	mg/l	converts to:	1952	lbs/day
TKN :	0	mg/l	converts to:	0	lbs/day

The pond volume is found using the following equation:

V = D/3 (As + Ab + squareroot(As * Ab))
Where:

As = surface area D = water depth
Ab = bottom area V =cell volume in cu.ft.

Detention time is found by dividing volume by daily flow.

	Cell 1		Cell 2		Cell 3	
Width:	300.00	ft.	150.00	ft.		ft.
Length:	600.00	ft.	300.00	ft.		ft.
Depth:	15.00	ft.	12.00	ft.		ft.
Volume:	2129726	cu.ft.	418856	cu.ft.	0	cu.ft.
Capacity:	15930352	Gal	3133043	Gal	0	Gal
Det.time:	13.62	Days	2.68	Days	0.00	Days

Oxygen required for BOD removal

For this application we are using: 2.00 lbs of O2 for each pound of BOD per day (under working conditions). A residual oxygen level of 2.00 mg/l should be maintained in the pond at all times.

BOD Oxygen requirement calculation.

16198 lbs of BOD/day x 2.00 lb of O2/lb BOD = 32396 lb 02/day

TKN Oxygen requirement calculation:

0 lbs of TKN/day x 4.60 lb of O2/lb TKN = 0 lb 02/day

Total Oxygen required per day is the total of the BOD and TKN demands.

32396 lbs/day + 0 lbs/day = 32396 lbs O2 (under field conditions

MERRICK
Engineers & Architects

Engineering Calculation Sheet

Date 2/27/98 Sheet of
Contract
Calculation No.

Subject NIREL

Revision	By	Date	Chk'd	Date

AEROBIC LAGOON COST

1036,85 ft³

SIZE: 2@ 500' × 250' × 10' = 1250000 ft³
= 46300 yd³

EXCAVATION @ $5.00 per yd³ = $463,000 191,867

LINER: 2@ 500 × 250 = 125000 ft² 250,000

@ $1.50 per yd² = $\frac{250,000}{9}$ × 1.50 = $41,700

total = 463,000
41,700
$504,700
$505

20550
212,718

Per Phone Conversation w/ Steve 8/28/98:

Increasing BOD to ~ 150,000 mg/L will increase price to

```
Equipment Num        :: T-610
Eqipment Name        :: Clarifier
Associated PFD       :: PFD-P100-A603
Equipment Type       :: CLARIFIER
Equipment Category   :: SEPARATOR
Equipment Description:: 195289 gal, Residence time 3.9 hr.
Number Required      :: 1
Number Spares        :: 0
Scaling Stream       :: 618
Base Cost            :: 174385.00
Cost Basis           :: VENDOR
Cost Year            :: 1998
Base for Scaling     :: 185782.000
Base Type            :: FLOW
Base Units           :: KG/HR
Install. Factor      :: 1.9600
Install. Factor Basis:: VENDOR
Scale Factor Exponent:: 0.5100
Scale Factor Basis   :: GARRETT
Material of Const    :: CONCRETE
Utility Calc.        :: ASPEN FORT BLCK
Utility Stream       :: WT610
Utility Type         :: POWER
Date Modified        :: 01/13/99
Notes                :: Expected Power Req: 4 kW.
```

Eq. No.	T-610		
Eq. Name	Clarifier		
Associated PFD	A603		
Stream for Design	618		
Stream Description	Primary Inlet		
Flow Rate	185782	Kg/hr	R9809G
Average Density	0.984	g/CC	R9809G
Flowrate	831.1	gpm	
Flowrate	49863.9	gph	
Residence Time	3.9	hr	Back calculated from Information below
Calculated Volume	195,289	gal	
Power Requirement	5	hp	Estimated
	3.7	kW	
Volume	180,000	gal	Phoenix Bio-Systems, Inc
Flowrate	766	gpm	Merrick Appendix F "Case 1 - Equalization"
Vendor Equipment Cost	**$ 155,000**		Per above
Vendor Installation Cost	$ 115,000		Per above
Prorated Additional Piping			
			Phoenix Bio-Systems, Inc. Merrick Appendix
Total Cost of Option	$3,737,350		F "Case 1",
Overhead Portion	$760,000		Design Engineering Fee + Site Preparation
Project Cost Less Overhead	$2,977,350		
Overall Piping & Installation	$371,600		Controls+Temp Control+Piping
Overall Piping & Inst %	12.48%		
Installation Cost Above	$115,000		From above
Additional Prorated Installati	$33,698		
Total Installation Cost	**$148,698**		Per above, extra piping and inst. Prorated
Installation Factor	**1.96**		
Scaling Exp	0.51		
Cost	**$ 174,385**		Scaled to 831 gpm from 766 gpm
Scaling Stream	618		
Scaling Rate	185782		
Scaling Units	Kg/hr		

CLIENT: NREL
PHONE/FAX:
PROJECT NUMBER:
DATE: 5/18/98
TYPE: Anaerobic/Aerobic
LOAD RATE: 12 g/l/d & 0.55 g/l/d
COD: 4,173 mg/l and 334 mg/l
FLOW: 766 gpm

ITEM	Description	Qty	Unit Cost	Installation	Q x UC + I	Totals
Treatability						
Laboratory Analysis						
Preliminary Design						
						$0.00
Equalization						
Dimensions T-602	36'd x 44'h AOS SI SI					
602 Capacity (gal)	330000 gal	1	325,000.00	86,000.00	411,000.00	
				51,296 PIP & INST		~~$411,000.00~~
				$137,296		$462296
Main Reactor						
Dimensions	24'd x 60'h AOS	2				
Capacity (gal)	385,000 gal	1	350,000.00	95,000.00	445,000.00	
Distribution Manifold	ICM s/s	8	4,950.00	10,500.00	50,100.00	
Overflow collection system	PVC	2	3,500.00	7,500.00	14,500.00	
Separator	10 x 12 Custom	2	24,500.00	17,500.00	66,500.00	
Sample Cocks	1" PVC	24	50.00	1,200.00	2,400.00	
Packing	TriPack PP	2600	12.00	2,500.00	33,700.00	
Insulation	9000 ft2	9050	7.00		63,350.00	
						$675,550.00
Decarbonator						
Capacity	3,000 gal	1	14,500.00	17,500.00	32,000.00	
Dimensions	6'd x 18'h				0.00	
Distributor	s/s	1	4,850.00	8,700.00	13,550.00	
Packing	TriPack 3.5 PP	400	12.00	1,500.00	6,300.00	
Demister		1	1,500.00	1,000.00	2,500.00	
Gratings	FRP	1	3,500.00	3,000.00	6,500.00	
Fan	3 hp	1	1,250.00	2,200.00	3,450.00	
Drain						
						$64,300.00

Controls						
Field Instruments		1	85,000.00	8,500.00	93,500.00	
Pressure Ind		12	250.00	750.00	3,750.00	
Temp Indicators		12	250.00	750.00	3,750.00	
pH Controller		4	2,500.00	2,000.00	12,000.00	
Biogas Meter		1	4,300.00	1,250.00	5,550.00	
Panel		1	3,800.00	2,250.00	6,050.00	
PLC		1	9,500.00	5,500.00	15,000.00	
Control computer		1	10,500.00	7,500.00	18,000.00	
Software		1	4,000.00	12,000.00	16,000.00	
						$173,600.00 *
Temp Control						
Hot water heater		0	0.00	0.00	0.00	
Heat Exch		2	6,500.00	14,500.00	27,500.00	
						$27,500.00 *
BioGas Scrubber						
Capacity	300 cf	1	6,500.00	7,600.00	14,100.00	
Grating	FRP	1	1,800.00	3,350.00	5,150.00	
Media	280	280	7.50	1,550.00	3,650.00	
						$22,900.00
Piping						
PVC		1	75,000.00	55,000.00	130,000.00	
Heat trace/Insulate		1	12,500.00	28,000.00	40,500.00	
						$170,500.00 *
Macronutrient Tank						
Tank	5000	1	8,500.00	3,500.00	12,000.00	
Nutrient Feed Pump		1	1,500.00	3,800.00	5,300.00	
Micronutrient Tank			10			
604 Tank	M 604 3000	1	4,500.00	3,500.00	8,000.00	
Nutrient pump		1	1,500.00	3,800.00	5,300.00	
Caustic Tank			6			
Caustic Dosing Pump	500 gpd	1	1,150.00	3,700.00	4,850.00	
Tank	5500 gal	1	9,500.00	17,500.00	27,000.00	
Iron Tank	200 gal	1	550.00	500.00	1,050.00	
Metering pump		1	850.00	1,550.00	2,400.00	
Phosphate Tank	1000 gal	1	2,500.00	2,500.00	5,000.00	
Metering pump	50 gpd	1	850.00	1,550.00	2,400.00	
						$73,300.00
			#31,400			

Flare						
Burner	150 CFM	1	8,500.00	4,000.00	12,500.00	
Auto pilot,N-gas,air		1	4,500.00	3,500.00	8,000.00	
						$20,500.00
System Feed Pump						
Cent	766 gpm, 40' TDH s/s	2	4,900.00	2,700.00	12,500.00	
System Recirc Pump						
Cent	1500 gpm 70' TDH s/s	2	8,000.00	4,500.00	20,500.00	
						$20,500.00
Aerobic Secondary						
Feed Pump	766 gpm 40' TDH s/s	2	4,900.00	3,500.00	13,300.00	
Aerated Lagoon	0.9 mgal	1		500,000.00	500,000.00	
Floating aerators	4x25 hp, 2 x 50 hp	6	25,000.00	22,000.00	172,000.00	
						$685,300.00
610 Clarifier T.610	180,000 gal	1	155,000.00	115,000.00 +33,750 148750	~~270,000.00~~	$ 303,750
Sludge pumps	2x25hp PD s/s	2	5,500.00	2,900.00	13,900.00	
Effluent pumps/wet wells	2x25hp cent	2	3,500.00	10,500.00	17,500.00	
						$301,400.00
Belt Thickener		1	110,000.00	42,000.00	152,000.00	
Piping	Yard	1	42,000.00	67,000.00	109,000.00	
Sludge holding Tanks/Load out		1	45,000.00	25,000.00	70,000.00	
						$331,000.00
Sand Filters						
VortiSand Filters	0	0	0.00	0.00	0.00	
Surge Tanks	0	0	0.00	0.00	0.00	
						$0.00
Chlorinator						
Hypo Storage/feed Tk	0	0	0.00	0.00	0.00	
Metering system		0	0.00	0.00	0.00	
Contact Tank	0	0	0.00	0.00	0.00	
C.T. Aerator	0	0	0.00	0.00	0.00	
						$0.00

Design Engineering Fee	all	1	250,000.00	250,000.00	
Design Drawings					
Shop Drawings					
Wiring Diagrams					
Power Requirements					
Operating Manuals					
Administratative					
					$250,000.00 +
Site Installation		1		295,000.00	
Site Preparation					
Off-Loading					
Pads					
Power Hook-Up					
Process Hook-Up					
Weather Protection					
Power Outage Protection					
Buildings	Control Building	1		125,000.00	
Fencing					
MCC				55,000.00	
Site Electrical					
Subcontractors					
					$475,000.00 +
Permits and Fees				35,000.00	
Taxes					
Insurance					
					$35,000.00 +
TOTAL					**$3,737,350.00**
Plus 12 % Contingency					**$4,185,832.00**

TOTAL 3,737,350
Less OVHD # 760,000
SUB 2,977,350
PIP & INST * 371,600
PIP & INST % SUB 12.5%

Equipment Num	::	T-630
Eqipment Name	::	Recycled Water Tank
Associated PFD	::	PFD-P100-A601
Equipment Type	::	FLAT-BTM-STORAGE
Equipment Category	::	TANK
Equipment Description	::	13218 gal, Residence time 20 min, 2.5 psig
Number Required	::	1
Number Spares	::	0
Scaling Stream	::	602
Base Cost	::	14515.00
Cost Basis	::	VENDOR
Cost Year	::	1998
Base for Scaling	::	179446.000
Base Type	::	FLOW
Base Units	::	KG/HR
Install. Factor	::	1.4000
Install. Factor Basis	::	DELTA-T98
Scale Factor Exponent	::	0.7450
Scale Factor Basis	::	VENDOR
Material of Const	::	CS
Date Modified	::	01/13/99

Eq. No.	T-630			
Eq. Name	Recycle Water Tank			
Associated PFD	A601			
Stream for Design	602			
Stream Description	Primary Inlet			
Flow Rate	179446	Kg/hr	R9809G	
Average Density	0.999	g/CC	R9809G	
Flowrate	790.7	gpm		
Flowrate	47440.1	gph		
Residence Time	20	min	Assumed	
Calculated Volume	15,813	gal		
Volume	13,218	gal	Springs Fabrication	
Vendor Equipment Cost	$ 11,300		Per above	
50% Larger	$ 17,000			19,827
50% Smaller	$ 7,500			6,609
Scaling Exp (Small->Large)	0.745			
Cost	**$ 14,515**		Scaled Cost	
Scaling Stream	602			
Scaling Rate	179446			
Scaling Units	Kg/hr			

SPRINGS FABRICATION, INC.
4751 Fox Street • Denver, CO 80216
Fax: (303) 292-5430 Phone: (303) 294-0585
e-mail: gary@springsfab.com

Industrial Metal Products
ASME Pressure Vessels – Tanks – Piping – Skids
Filter Housings – Stainless Alloy Products – Frames

Fax Cover Sheet

To:	Mr. Jim Kassian	**From:**	Gary Quick
Company:	Merrick & Company 1304	**Pages:**	One
Phone:	751-0741	**Date:**	August 26, 1998
Fax:	751-2581	**Re:**	Budgetary Tank Figures T-630

☐ Urgent X for Review ☐ Please Comment ☐ Please Reply

Message: Dear Mr. Kassian

Following is the estimate based on our phone conversation today. Tanks were figured with flat heads and one Bottom Sludge clean out door. Dimensions on the tank are 15' diameter and 10' side shell. 13218 gal

STD DUTY

STD — $11,300
50% Larger — $17,000
50% Smaller — $7,500

Per phone w/Gary
Aug 26, 1998

HEAVY DUTY

Standard size (as above)	$17,800.00
50% larger	$26,700.00
50% smaller	$11,800.00

Thank you for the inquiry Jim. Hope this helps, please let me know if we can be of any further help.

Darren Hunt, one of our project managers did the estimating.

Sincerely,

Gary Quick

T-704 Firewater Storage tank

~~From I:\Process\3104\Softwood\P9807C-1~~

~~444,777 gal~~

~~$(.7854 \times \phi^2 \times (H) \times 7.48) = \boxed{60'\phi \times 22' \text{ tall}} = 465,280$ gal~~

~~$22'$ tall $\rightarrow \frac{62.4 \ \#/ft^3}{1728 \ in^3/ft^3} \times (22 \times 12) = 9.53$ psig~~

~~.1875 wall $\approx$ S.F. 4 using A36 9150 PSI~~

T-630 Recycled H_2O TANK

13095 gal

$(.7854 \times \phi^2 \times (H) \times 7.48) = \boxed{12'\phi \times 18' \text{ tall}} = 15250$ gal

$18'$ tall $\rightarrow \frac{62.4}{1728} \times (18 \times 12) = 7.8$ psig

.125 wall $\approx$ SF=8 using A36 4500 psi

Jim Kassian
8-26-98

Appendix G

Wastewater Treatment ASPEN Model

Wastewater Treatment Model
Victoria Putsche
November 11, 1998

A wastewater treatment model has been developed and incorporated into an NREL base model, W9806F. The resulting model, P9808B, has been checked into the Basis database. This report describes the assumptions behind the wastewater model. Attachment 1 contains a print-out from the model describing all of the changes, applicable ASPEN code (e.g., flowsheet, design-specs), and a block flow diagram with all design-specs and FORTRAN blocks for this section.

The overall design of the wastewater treatment system has not changed significantly over the NREL base model. It is still comprised of anaerobic digestion (T-606) followed by aerobic treatment (T-608) (Ruocco 1998). The new model, however, has simplified the flowsheet somewhat by replacing the RYIELD reactor with a user subroutine (USRANR). Now, the unreactable components (e.g., ash, lignin, water) do not need to be separated out prior to the digestor. Thus, the blocks associated with the separation and re-mixing (ASHSEP, UNCONVT) have been eliminated.

Another simplification of the design is in the aeration basins. Originally, the system was an oxygen fed system with a pressure swing adsorption unit to separate oxygen from air. The current design is an aerated lagoon with floating aerators. Since it is a lagoon, no temperature control will be provided. It will receive the effluent from the anaerobic digestors (618) at the temperature of digestion (35 ^{o}C) and so the aerobic feed cooler, H-601, is no longer needed. The temperature of the aerobic system was decreased to ambient, 20 ^{o}C, in the model since it is a lagoon. Any heat removed by the temperature drop is not included in the modeling since it represents heat dissipation to the atmosphere and would not require a cooling load.

As noted earlier, the anaerobic system is modeled using a user subroutine USRANR. A copy of the subroutine is also in the database as well as Attachment 2. The subroutine requires 5 real inputs from the user (in this order): chemical oxygen demand (COD) conversion, fraction of theoretical methane yield on COD, fraction of cell mass yield on COD, mole fraction of methane in the outlet gas, and the fraction of soluble sulfate components that are converted to hydrogen sulfide. In the current design, the COD conversion is set to 0.9, the fraction of theoretical methane conversion is 1.0, the fraction of COD converted to cell mass is 0.03 (Ruocco 1998). Testing of the enzyme sample showed a conversion of 73% of the COD, but it is expected that after full incubation, this sample would show conversions of 90-100% (Pinnacle 1998). Thus, the COD conversion factor is reasonable. It should be noted that the softwood process obtained digestibilities that were similar to the enzyme case and so the assumptions outlined above would be valid for this process. Tests on the countercurrent sample, however, were not promising with conversions of only 36% (Pinnacle 1998). When this process is modeled, different assumptions or more information should be obtained.

The expected fraction of methane in the off-gas is set to 0.75; in general, depending on the complexity of the feed, it can vary from 50 to 90% (Ruocco 1998). In the testing performed on the NREL SSCF effluent from the enzyme process, the methane concentration was only 61.4% (Pinnacle 1998). Pinnacle expects that without CO_2 removal, the maximum methane concentration would be 70% (Nagle 1998). The proposed process, however, has a proprietary decarbonator technology which will likely increase the methane concentration. Thus, the assumed value of 75% for the enzyme case is reasonable.

The theoretical yield of methane on COD is 350 liters/kg COD converted (0.229 kg/kg at 25 ^{o}C). The mass conversion decreases to 0.221 kg/kg at the conditions of the digester (i.e., 35 ^{o}C). The subroutine uses the total COD loading in kg/hr (CODTOT) from the COMMON block, WWLOAD and the values specified by the user to determine the amount of methane and cell mass produced. Only soluble, carbon-containing compounds are considered to be converted. However, insoluble components such as cellulose and xylan may be converted by as much as 40% and 50%, respectively (Nagle 1998). For conservatism, no conversion of these compounds was assumed. One soluble compound, ammonium acetate, is currently modeled in the CISOLID substream, but will be converted in wastewater treatment.

After calculating the amount of methane and cell mass generated, the routine determines the amount of CO_2 that could be produced via mass balance (CO_2(A)) . If this amount is less than that predicted assuming that methane is present at 75 mol% in the off-gas (CO_2(B)), then the amount of CO_2 produced is set equal to the CO_2(A) and the amount of methane in the off-gas will be greater than 75 mol%. If CO_2(A) is greater than CO_2(B), then the amount of CO_2 produced is set equal to 25 mol% of the off-gas and the remaining mass (excess CO_2) is assumed to be converted to water, see Attachment 5.

For example, a kg of glucose with a COD of 1.07 will produce 1.07 kg of COD which corresponds to 0.213 kg of methane (i.e., 0.221 kg CH4/kg COD*1.07 kg COD*90% conversion) and 0.0321 kg of cell mass (i.e., 0.03 kg cell mass/kg COD*1.07 kg COD). Since only 1 kg (not 1.07 kg) of glucose can be converted, the amount of mass available for conversion to carbon dioxide is 0.7549 kg (i.e., 1 - 0.213 - 0.0321). On a molar basis, the biogas would then be comprised of 0.0133 kg-moles of methane (43.6 mol%) and 0.0172 kg-moles of carbon dioxide (56.4 mol%). If the amount of methane is fixed at 75 mol%, the amount of carbon dioxide can only be 25% and so the amount produced must be reduced. The remaining mass is assumed to be converted to water.

Attachment 2 contains a spreadsheet showing this calculation for most of the components present in the wastewater. In general, as shown on the spreadsheet, the predicted split between methane and CO_2 in the off-gas is roughly 50:50 mol% for all compounds. Thus, in all cases, the amount of CO_2 produced will be fixed at 25 mol% and some water will be generated.

In addition to these products, anaerobic digestion will degrade sulfur-containing compounds to H_2S and other compounds. For this analysis, all soluble sulfur-containing compounds (e.g., sulfuric acid, ammonium sulfate) are assumed to be degraded on a mole per mole basis to hydrogen sulfide. The remaining mass is assumed to be converted to water. For example, a mole of ammonium sulfate (MW 132) would produce one mole (34 g) of hydrogen sulfide and 98 g of water. A mole of sulfuric acid (MW 98) would also produce one mole (34 g) of hydrogen sulfide and 64 g of water. On a mass conversion basis, 26% of the mass of ammonium sulfate and 35% of the sulfuric acid are converted to hydrogen sulfide, respectively.

As in the methane calculations, one soluble component, ammonium sulfate, is currently carried in the CISOLID substream. Gypsum, an insoluble component, will also be degraded to H_2S (Nagle 1998a). Although it is not currently present in the waste streams, the subroutine should be modified so that gypsum is also converted.

The assumption of 100% conversion of all sulfur-containing compounds to hydrogen sulfide may need to be revisited. The microbes will likely have an upper tolerance level. In fact, levels of 200-1,500 ppm may be considered toxic (Nagle 1998).   Finally, the production of H_2S may have a negative effect on the production of methane due to competition for hydrogen. In general, for every mole of H_2S produced, the potential methane production is decreased by 0.5 moles (Nagle 1998). Thus, the subroutine should be changed to better reflect expected yields.

The subroutine does not perform a heat balance. Any load, however, is expected to be negligible and can generally be accomplished with ambient air cooling. The stream is flashed externally in T606FLSH.

The aerobic system is modeled as an RSTOIC block. In this block, it is assumed that 90% of the inlet COD is converted to CO_2 and water (60%) and cell mass (30%). In the conversion to cell mass, no attempt is made to balance the atoms; one pound of cell mass is produced for every pound of component degraded. Thus, the stoichiometric coefficient for cell mass is equivalent to the ratio of the component molecular weight to the cell mass molecular weight (i.e., kg component/kgmol component/kg cell mass/kg mol cell mass). Since the atoms are not balanced and the heating value of the cell mass is greater than most components, for every pound of cell mass generated, there is a net increase in the heat available. This is not problematic as long as the overall heat balance over the reactor does not increase. For the proposed system, (i.e., 60% aerobic digestion and 30% conversion to cell mass), the heat content of the products is less than the heat content of the feed. This reduction is due primarily to the 2 to 1 ratio of combustion products to cell mass. If the conversion of cell mass rises significantly, this may no longer hold true. Attachment 3 contains a print-out of a spreadsheet that can be used to calculate the heat in and out. This spreadsheet along with the spreadsheet showing the predicted methane/CO_2 split are contained in a single workbook, WWTCALCS.XLS that has been added to the database.

As in the original design, the wastewater treatment system requires chemicals and nutrients. Table 1 provides a summary of typical addition rates (kg/kg COD) and costs (Ruocco 1998). In addition, typical costs for these components are also provided (Ruocco 1998).   All of these chemicals will be modeled as the component WNUTR in stream 630 and they are assumed to always be added in the same proportion. The flowrate of this stream is controlled by the FORTRAN block WWNUT1. Here, the total for all of the components in kg/kg COD (3.67E-2) is ratioed against the inlet COD loading. The cost for these nutrients was determined as the average of all costs ($0.11/lb).

Table 1
WWT Nutrient and Chemical
Demands and Costs

Chemical	**kg/kg COD**	**($/kg)**
Nitrogen (Urea)	2.7E-3	0.44
Phosphate (H_3PO4)	9.0E-4	0.35
Micro-Nutrients	1.5E-4	1.11
Caustic	3.3E-2	0.22

Following aerobic treatment, polymer is added for the filter press. The polymer is also modeled as the component WNUTR in stream 631. Addition of the polymer is controlled by the FORTRAN block WWNUT2. The cost of the polymer is $2.50/lb and it is added at 7.63E-4 kg/kg COD (Ruocco 1998).

Three other FORTRAN blocks, CODCALC1, CODCALC2 and CODEND were developed to calculate the COD and biochemical oxygen demand (BOD) for the anaerobic digestor inlet (613), the aerobic digestor inlet (618) and the effluent from the process (619A), respectively. In all cases, the COD is equivalent to the theoretical oxygen demand for complete combustion. Only soluble, carbon-containing compounds are included in the calculation. As noted earlier, ammonium acetate, while in the CISOLID substream, is soluble and so will contribute to the COD loading.

COD is a measure of the amount of oxygen required to convert all of the carbon in a specific compound to carbon dioxide. Any reasonable units (e.g., moles oxygen/moles component) may be used, but in this analysis, the units are kg oxygen/kg component. For example, the COD of glucose is 1.07 kg oxygen/kg compound and is calculated as follows:

$$C_6H_{12}O_6 + 6\ O_2 \quad = \quad 6\ CO_2 \ + \quad 6\ H_2O$$

COD of glucose = (6 kgmol O_2*32 kg/kgmol)/(1 kgmol glucose*180 kg/kgmol)

COD of glucose = 1.07 kg oxygen/kg glucose

The COD values used for the components in the NREL process are summarized in Table 2.

Table 2
Component COD Factors

Component	COD Factor (kg COD/kg)
C-6 and C-5 Sugars and Oligomers	1.07
Cellobiose	1.07
Ethanol	2.09
Furfural	1.67
Lactic Acid, Acetic Acid	1.07
Glycerol	1.22
Succinic Acid	0.95
Xylitol	1.22
HMF	1.52
Soluble Solids	0.71
Soluble Unknown	1.07
Corn Oil	2.89
Acetate Oligomers	1.07
Acetate	1.07

As shown on the table, the COD for most components is slightly greater than unity. This approximation agrees well with practice; CODs of sugar-based streams generally range from 1 to 1.1 (kg COD/kg component) (Nagle 1998a). This method of approximation results in values that are similar to tests performed on SSCF effluent that had been stripped of ethanol (Pinnacle 1998; Evergreen Analytical 1998). The predicted COD using the factors in Table 2 and the composition (without ethanol) provided by McMillan (1998) is 28,398 mg/l. The average of 3 measured values (Pinnacle 1998; Evergreen Analytical 1998) is 27,199 mg/l. Comparison of a more detailed compositional analysis of the sample could not be completed due to possible contamination (McMillan 1998a). Attachment 4 contains the measured COD values as well as a spreadsheet showing the projected COD value.

In the initial model, the BOD is calculated as 70% of the COD for all waste streams. This approximation agrees well with published ranges for COD and BOD for similar wastewater

(Perry 1998). Data on SSCF effluent predict a lower BOD/COD ratio, with an average value of 52% for all technologies (Evergreen Analytical 1998). The wastewater in the model, however, will have a different composition than that analyzed. In addition, it is expected that this ratio will change through each treatment step. Based on the projected wastewater compositions and the treatment system, the estimated BOD/COD ratio is 0.50 for the influent to anaerobic digestion, 0.20 for the influent to aerobic treatment and 0.10 for the system effluent (Ruocco 1998). Since BOD is a laboratory test and cannot be specifically predicted, the ratios provided above are estimates based on experience with other wastewater systems. The FORTRAN blocks CODCALC1, CODCALC2 and CODEND in the ASPEN model should be updated with the new BOD/COD ratios.

The COD calculations outlined above correspond to the COD loadings for anaerobic digestion. In aerobic treatment, nitrogen-containing compounds such as ammonium acetate will have a significant oxygen demand (e.g., 4.43 kg O_2 required per kg of NH_3).

Since ammonia is not converted in anaerobic digestion, the contribution of the reduced nitrogen compounds is <u>not</u> included in the overall COD calculation. In aerobic treatment, however, these compounds cannot be ignored. This fact requires two significant changes to the model. The first is that reduced nitrogen compounds that are converted in anaerobic digestion (i.e., ammonium acetate and ammonium sulfate) must be treated differently in the ASPEN model. Currently, the carbon and sulfur portions of these compounds are converted to biogas and hydrogen sulfide, respectively, and the other portion is converted to water. This system incorrectly ignores the nitrogen in the effluent from anaerobic digestion. The second major change is in the FORTRAN block CODCALC2. The current COD values are the same as those listed above in Table 3. As discussed, these COD do not include the contribution of reduced nitrogen. This contribution must be accounted for in aerobic treatment.

To remedy this situation, the following specific changes should be made to the ASPEN model:

1. The reduced nitrogen compounds should be carried through the wastewater treatment system as their component ions. Thus, an RSTOIC block should be added prior to the anaerobic system. Here, ammonium acetate would be converted to ammonia and acetate and ammonium sulfate would be converted to ammonia and sulfuric acid.

2. The FORTRAN block CODCALC1 would then need to be modified such that the COD value for acetate was 1.07.

3. Within the anaerobic digestion subroutine, no significant changes would be required except that ammonium sulfate would no longer be converted to hydrogen sulfide and ammonium acetate would no longer be converted to methane, carbon dioxide and water. The new substances, acetate, sulfuric acid and ammonia are already correctly handled in the subroutine. That is, acetate is converted to biogas; sulfuric acid is converted to hydrogen sulfide and water; and ammonia is not changed.

4. As noted earlier, the FORTRAN block CODCALC2 must be modified so that all reduced nitrogen compounds are included in the COD calculation. Since all of these compounds are now noted as ammonia, a new COD factor of 4.43 should be added and applied to ammonia. Ammonium hydroxide will also have a COD demand of 2.15.

5. The FORTRAN block that calculates the air addition, AERAIR, should be modified so that there is no excess air.

6. The aerobic reactor should be modified so that the ammonia-containing compounds are converted to nitrates as follows:

$$NH_3 + 2.25\ O_2 = NO_3 + 1.5\ H_2O$$

A conversion efficiency of 98% should be used for this reaction.

7. Finally, the FORTRAN block POWER should be modified so that the work stream for the aerators is correct. Each kg of oxygen required uses 2 hp-hr of energy. This should be added to the FORTRAN block as well as an appropriate work stream. The current system comprised of a compressor with an associated work stream should be deleted and replaced as outlined above.If these changes are made, it is expected that the ASPEN model will correctly simulate the wastewater treatment system. Other strategies would also likely work, but this appears to be the most straightforward.

References

Evergreen Analytical. 1998. Analysis Report, Lab Sample Numbers: 98-1697-01, 98-1593-01, 98-1609, April 22, 23, 30.

McMillan, J. 1998. Composition of post SSCF liquors, Memorandum to R. Wooley, June 10.

McMillan, J. 1998a. Personal communication, August 28.

Nagle, N. 1998. Personal communication, August 31.

Nagle, N. 1998a. Personal communication, August 27.

Perry, R.H. and Green, D.W. 1998. Perry's Chemical Engineers' Handbook, 7th edition, McGraw-Hill, New York, pg. 25-62.

Pinnacle Biotechnologies International, Inc. 1998. "Characterization and Anaerobic Digestion Analysis of Ethanol Process Samples", July.

Ruocco, J. 1998. Personal communication and cost estimates.

Attachment 1
Model Changes, ASPEN Code
and ASPEN Block Flow Diagram

```
;*****************************************************************************
;*****************************************************************************
;**                      NREL PROTECTED INFORMATION                          **
;*****************************************************************************
;*****************************************************************************
; NREL Biomass to Ethanol Process
; NREL Protected Information
; Best Case Cofermentation (4_96a.INP)
;  Modified to include the NREL Biofuels Databank of Physical Properties
; Authors: Vicky Putsche, Bob Wooley, Mark Ruth, Kelly Ibsen
; Date: April 26, 1996
;
;  Changes
; P9808B.INP; 08/18/98 VLP
;  WWT Changes
; 1. Deleted ASHSEP and UNCONVT blocks and corresponding streams.
; 2. Deleted O2/N2 separator (M608) because it is not needed (J. Ruocco)
; 3. Changed the anaerobic and aerobic temperatures to be 35 and 21C,
;    respectively, based on information from J. Ruocco
; 4. Modified the conversions in the aerobic system, T608, to be
;    60% conversion to CO2 and H2O and 30% to cell mass.  Only soluble
;    components will be degraded.
; 5. Modified FORTRAN WWNUTR1 to be based on the COD loading to
;    anaerobic digestion.  It controls all chemical (base) and nutrient
;    addition (H3PO4, urea, micronutrients) to anaerobic digestion
; 6. Added the FORTRAN block WWNUTR2 to control polymer addition to
;    aerobic treatment based on the COD loading to the aerobic system.
; 7. Modified excel costing spreadsheet (W9806_) to include new costs
;    for anaerobic and aerobic treatment chemicals.
; 8. Deleted aerobic digestor feed cooler (H-606) and corresponding
;    heat stream QH606 since cooling to the aerobic system is not
;    required (J. Ruocco).  The lower process temperature in aerobic
;    treatment is due to ambient cooling only.
; 9. Added polymer addition stream 631 to S614, the belt press.
; 10. Added stream 631 to the sensitivity block.
; 11. Changed aerobic cell conversion to be based on a mass basis without
;     balancing atoms.
; 12. Replaced RYIELD anaerobic digester (T-606) with a user block.
; 13. Commented out agitation streams WT602 (Equalization Basin),
;     WT604 (Nutrient addition), WT606 (Anaerobic Digestion), WT608
;     (Aerobic Digestion) based on information from J. Ruocco
; 14. Added block NUTMIX to add nutrients to anaerobic digestion.  Also
;     added this to sequence 10
; 15. Changed stream reference for P-606 in PUMPS to 618 from 616 since
;     it was deleted.
; 16. Changed the stream reference in the massflow sensitivity block
;     from 616 to 618.
; 17. Added H2S as a component
; 18. Changed 531 destination from S-600 to the boiler M803MIX
; 19. Changed water recycle in WWT (627) from anaerobic digestion to
;     aerobic
; 20. Added WWTSIZ to calculate the vessel volumes for anaerobic
```

```
;     digestion and aerobic treatment.  Added the vessel volume
;     variables, ANVOL and AERVOL to the sensitivity study with labels of
;     ZZZNANA, and ZZZOAER


FLOWSHEET A600
;THIS SECTION MODELS THE WASTEWATER TREATMENT AREA.
    BLOCK DCOOL2   IN=525  OUT=600 QDCOOL2
    BLOCK S601     IN=600  OUT=602 601
    BLOCK T630     IN=602  OUT=603 610
    BLOCK FWMIX    IN=516 603 604  OUT=606
    BLOCK RWSPLT   IN=606  OUT=219 430 411
    BLOCK S600     IN=520 247 821 535 1044  OUT=612
    BLOCK H602     IN=612  OUT=613 QH602
    BLOCK NUTMIX   IN=613 630  OUT=632
    BLOCK T606     IN=632  OUT=613C
    BLOCK T606FLSH IN=613C  OUT=614 618
    BLOCK M606     IN=614  OUT=615 WM606
    BLOCK M608A    IN=626  OUT=619 WM608A
    BLOCK T608     IN=618 619  627 OUT=619A
    BLOCK T608FLSH IN=619A  OUT=620 621
    BLOCK T610     IN=621  OUT=625 624
    BLOCK S614     IN=625 631  OUT=627 623
    BLOCK MPOW6    IN=WS601 WC601 WC614 WS614 OUT=WMP6

;------------------------------------------------------------
;    DIGESTION (WASTE WATER TREATMENT) BLOCKS - AREA 6000
;----------------------------------------------------------
;
BLOCK T630 FSPLIT
    DESCRIPTION "RECYCLE WATER AND WWT LIQUID SEPARATOR"
    FRAC 610 .750
;
BLOCK RWSPLT FSPLIT
    DESCRIPTION "RECYCLE WATER SPLITTER"
    FRAC 219 0.8/430 .001
;THE FRACTIONS LISTED ARE ASSUMPTIONS.  THE ACTUAL VALUES ARE
;DETERMINED BY THE FORTRAN BLOCK RECYCLE.
;
BLOCK S600 MIXER
    DESCRIPTION "TANK T-603 TO MIX PROCESS WASTEWATER AND OTHER WASTES"
    PARAM PRES=2
;
BLOCK FWMIX MIXER
    DESCRIPTION "TANK T-630 FOR MIXING FRESH H2O AND RECYCLE H2O"
    PARAM NPHASE=1 PHASE=L
;
BLOCK S601 SEP2
    DESCRIPTION "BEER BOTTOMS CENTRIFUGE"
    PARAM PRES=3.20
;THE FRACTIONAL SPLITS ARE BASED ON THE PDU VENDOR TESTS
;THAT SHOWED AN OUTLET SOLIDS CONCENTRATION OF
;30% AND 98% RECOVERY OF INSOLUBLE SOLIDS.  SOLUBLE
;COMPONENTS ARE SPLIT SO THAT THE LIQUID FRACTION OF
;EACH STREAM HAS THE SAME COMPOSITION.
    FRAC STREAM=601 SUBSTREAM=MIXED COMPS=                &
        H2O ETHANOL FURFURAL HMF  H2SO4 N2   CO2  O2  CH4  &
        NO  NO2  NH3  SOLSLDS  GLUCOSE XYLOSE GALACTOS     &
        MANNOSE ARABINOS UNKNOWN AACID LACID CNUTR WNUTR   &
        CSL OIL  DENAT GLUCOLIG CELLOB XYLOLIG MANOLIG     &
```

```
        GALAOLIG ARABOLIG ACETOLIG GLYCEROL SUCCACID       &
        XYLITOL                                          &
  FRACS=.10  .10     .10      .10  .10  .10  .10  .10  .10  &
        .10  .10  .10  .50      1.0     .10    .10         &
        .10      .10      .10     .10   .10   1.    .10     &
         1.  .10  .10  .10      .10     .10    .10         &
        .10      .10      .10      .10      .10            &
        .10
;ALL CNUTR & CSL SHOULD HAVE BEEN CONSUMED IN CELLULASE PRODUCTION &
;SO ANY REMAINING SHOULD GO OFF TO WWT SO THAT THE RECYCLE WILL BE
;CORRECT.  DENAT AND WNUTR SHOULD NOT BE IN THIS STREAM, BUT IF THEY
;ARE, THEY BEHAVE LIKE ANY LIQUID.
    FRAC STREAM=601 SUBSTREAM=CISOLID COMPS=CELLULOS XYLAN  &
        ARABINAN MANNAN GALACTAN LIGNIN BIOMASS CELLULAS    &
        ZYMO CASO4 CAH2O2 GYPSUM TAR ACETATE ASH            &
    FRACS=                                .980     .980   &
        .980     .980   .980     .980   .50     .50         &
        0.50 0.980 0.980  0.980  .98 .980    0.98
;
BLOCK T610 SSPLIT
    DESCRIPTION "CLARIFIER"
    FRAC MIXED 625 0.1
    FRAC CISOLID 625 1.0
;
BLOCK S614 SSPLIT
    DESCRIPTION "DEWATERING BELT FILTER PRESS"
    FRAC MIXED 623 0.1
    FRAC CISOLID 623 1.0
;
BLOCK DCOOL2 HEATER
    DESCRIPTION "DUMMY COOLER / AMBIENT COOLING IN S601"
    PARAM TEMP=40. PRES=.0
;
BLOCK H602 HEATER
    DESCRIPTION "COOLER TO BRING WASTEWATER TO ANAEROBIC TEMP"
    PARAM TEMP=35.0 PRES=.0
;
BLOCK T608 RSTOIC
    DESCRIPTION "AEROBIC DIGESTOR"
    PARAM TEMP=21.1 PRES=1.0
    STOIC 1 MIXED O2 -6.0 / GLUCOLIG -1.0 / H2O 5.0 / CO2 6.0
    STOIC 2 MIXED O2 -12.0 / CELLOB -1.0 / H2O 11.0 / CO2 12.0
    STOIC 3 MIXED O2 -6.0 / GLUCOSE -1.0 / H2O 6.0 / CO2 6.0
    STOIC 4 MIXED O2 -6.0 / HMF -1.0 / H2O 3.0 / CO2 6.0
    STOIC 5 MIXED O2 -5.0 / XYLOLIG -1.0 / H2O 4.0 / CO2 5.0
    STOIC 6 MIXED O2 -5.0 / XYLOSE -1.0 / H2O 5.0 / CO2  5.0
    STOIC 7 MIXED O2 -5.0 / FURFURAL -1.0 / H2O 2.0 / CO2 5.0
    STOIC 8 MIXED O2 -6.0 / MANOLIG -1.0 / H2O 5.0 / CO2  6.0
    STOIC 9 MIXED O2 -6.0 / MANNOSE -1.0 / H2O 6.0 / CO2  6.0
    STOIC 10 MIXED O2 -6.0 / GALAOLIG -1.0 / H2O 5.0 / CO2 6.0
    STOIC 11 MIXED O2 -6.0 / GALACTOS -1.0 / H2O 6.0 / CO2 6.0
    STOIC 12 MIXED O2 -5.0 / ARABOLIG -1.0 / H2O 4.0 / CO2 5.0
    STOIC 13 MIXED O2 -5.0 / ARABINOS -1.0 / H2O 5.0 / CO2 5.0
    STOIC 15 MIXED O2 -2.0 / ACETOLIG -1.0 / H2O 2.0 / CO2 2.0
    STOIC 16 MIXED O2 -2.0 / AACID -1.0 / H2O 2.0 / CO2  2.0
    STOIC 17 MIXED O2 -3.0 / LACID -1.0 / H2O 3.0 / CO2  3.0
    STOIC 18 MIXED O2 -.50 / UNKNOWN -1.0 / H2O .50 / CO2 .50
    STOIC 19 MIXED O2 -1.27630 / SOLSLDS -1.0 / H2O .740 /
                   CO2 1.0 / SO2 .00130
    STOIC 20 MIXED O2 -3.0 / ETHANOL -1.0 / H2O 3.0 / CO2 2.0
```

```
    STOIC 21 MIXED O2 -3.50 / GLYCEROL -1.0 / H2O 4.0 /CO2 3.0
    STOIC 22 MIXED O2 -3.50 / SUCCACID -1.0 / H2O 3.0 /CO2 4.0
    STOIC 23 MIXED O2 -5.50 / XYLITOL -1.0 / H2O 6.0 / CO2 5.0
    STOIC 24 MIXED O2 -2.75 / CISOLID NH4ACET -1.0 /
                   MIXED H2O 3.5 / CO2 2.0 / N2 0.5
;
    STOIC 25 MIXED GLUCOSE -1 / CISOLID BIOMASS 7.75281869
    STOIC 26 MIXED MANNOSE -1 / CISOLID BIOMASS 7.75281869
    STOIC 27 MIXED GALACTOS -1 / CISOLID BIOMASS 7.75281869
    STOIC 28 MIXED XYLOSE -1.0 / CISOLID BIOMASS 6.46062489
    STOIC 29 MIXED ARABINOS -1.0 / CISOLID BIOMASS 6.46062489
    STOIC 30 MIXED XYLITOL -1.0 / CISOLID BIOMASS 6.54746538
    STOIC 31 MIXED SOLSLDS -1.0 / CISOLID BIOMASS 0.71367586
    STOIC 32 MIXED UNKNOWN -1.0 / CISOLID BIOMASS 0.64607109
    STOIC 33 MIXED GLUCOLIG -1.0 / CISOLID BIOMASS 6.97628887
    STOIC 34 MIXED GALAOLIG -1.0 / CISOLID BIOMASS 6.97628884
    STOIC 35 MIXED MANOLIG -1.0 / CISOLID BIOMASS 6.97628884
    STOIC 36 MIXED XYLOLIG -1.0 / CISOLID BIOMASS 5.68440485
    STOIC 37 MIXED CELLOB -1.0 / CISOLID BIOMASS 14.7275927
    STOIC 38 MIXED FURFURAL -1 / CISOLID BIOMASS 4.13116442
    STOIC 39 MIXED HMF -1.0 / CISOLID BIOMASS 5.4269558
    STOIC 40 MIXED AACID -1.0 / CISOLID BIOMASS 2.58197779
    STOIC 41 MIXED LACID -1.0 / CISOLID BIOMASS 3.87296669
    STOIC 42 MIXED SUCCACID -1.0 / CISOLID BIOMASS 5.07788966
    STOIC 43 MIXED GLYCEROL -1.0 / CISOLID BIOMASS 3.9590326
    STOIC 44 MIXED OIL -1.0 / CISOLID BIOMASS 12.155542
    STOIC 45 MIXED ETHANOL -1.0 / CISOLID BIOMASS 1.97951631
    STOIC 46 CISOLID NH4ACET -1.0 / CISOLID BIOMASS 3.317135
;
    CONV 1 MIXED GLUCOLIG 0.6
    CONV 2 MIXED CELLOB 0.6
    CONV 3 MIXED GLUCOSE 0.6
    CONV 4 MIXED HMF 0.6
    CONV 5 MIXED XYLOLIG 0.6
    CONV 6 MIXED XYLOSE 0.6
    CONV 7 MIXED FURFURAL 0.6
    CONV 8 MIXED MANOLIG 0.6
    CONV 9 MIXED MANNOSE 0.6
    CONV 10 MIXED GALAOLIG 0.6
    CONV 11 MIXED GALACTOS 0.6
    CONV 12 MIXED ARABOLIG 0.6
    CONV 13 MIXED ARABINOS 0.6
    CONV 15 MIXED ACETOLIG 0.6
    CONV 16 MIXED AACID 0.6
    CONV 17 MIXED LACID 0.6
    CONV 18 MIXED UNKNOWN 0.6
    CONV 19 MIXED SOLSLDS 0.6
    CONV 20 MIXED ETHANOL 0.6
    CONV 21 MIXED GLYCEROL 0.6
    CONV 22 MIXED SUCCACID 0.6
    CONV 23 MIXED XYLITOL 0.6
    CONV 24 CISOLID NH4ACET 0.6
;
    CONV 25 MIXED GLUCOSE 0.3
    CONV 26 MIXED MANNOSE 0.3
    CONV 27 MIXED GALACTOS 0.3
    CONV 28 MIXED XYLOSE 0.3
    CONV 29 MIXED ARABINOS 0.3
    CONV 30 MIXED XYLITOL 0.3
    CONV 31 MIXED SOLSLDS 0.3
```

```
    CONV 32 MIXED UNKNOWN 0.3
    CONV 33 MIXED GLUCOLIG 0.3
    CONV 34 MIXED GALAOLIG 0.3
    CONV 35 MIXED MANOLIG 0.3
    CONV 36 MIXED XYLOLIG 0.3
    CONV 37 MIXED CELLOB 0.3
    CONV 38 MIXED FURFURAL 0.3
    CONV 39 MIXED HMF 0.3
    CONV 40 MIXED AACID 0.3
    CONV 41 MIXED LACID 0.3
    CONV 42 MIXED SUCCACID 0.3
    CONV 43 MIXED GLYCEROL 0.3
    CONV 44 MIXED OIL 0.3
    CONV 45 MIXED ETHANOL 0.3
    CONV 46 CISOLID NH4ACET 0.3
;
BLOCK M606 COMPR
    DESCRIPTION "OFF-GAS BLOWER"
    PARAM TYPE=ISENTROPIC PRES=2.360
;
BLOCK M608A COMPR
    DESCRIPTION "AEROBIC WWT REACTOR AIR BLOWER"
    PARAM TYPE=ISENTROPIC PRES=2.360
;
BLOCK T606FLSH FLASH2
    DESCRIPTION "FLASH FOR ANAEROBIC DIGESTION"
    PARAM PRES=1.0 DUTY=.0
;
BLOCK NUTMIX MIXER
    DESCRIPTION "ADDS CHEMICALS AND NUTRIENTS TO ANAEROBIC DIGESTION"
;
BLOCK T608FLSH FLASH2
    DESCRIPTION "FLASH FOR AEROBIC TREATMENT"
    PARAM PRES=.0 DUTY=.0
;
BLOCK MPOW6 MIXER
```

```
    DESCRIPTION "AREA 6000 MISCELLANEOUS WORK SUMMER"
;
BLOCK T606 USER
    DESCRIPTION "Anaerobic Digester"
    SUBROUTINE USRANR
    PARAM NREAL=5
    REAL VALUE-LIST=0.9 1.0 0.03 0.75 1.0
    FLASH-SPECS 613C TP TEMP=95 <F> PRES=1
;
;----------------------------------------------------------------
;                   DESIGN SPECS
;                   DIGESTER (AREA 6000)
;----------------------------------------------------------------
;
DESIGN-SPEC CFUGE3S
; Varies the split of water and most of the mixed components
; to reach a specified solids fraction in 601.  Works with
; fortran block CFUGESLD to vary not only water but several
; components
;
    DEFINE SOLIDS STREAM-VAR STREAM=601 SUBSTREAM=CISOLID   &
                  VARIABLE=MASS-FLOW
    DEFINE TMIXED STREAM-VAR STREAM=601 SUBSTREAM=MIXED     &
                  VARIABLE=MASS-FLOW
F     RATIO = SOLIDS / (TMIXED+SOLIDS)
F     WRITE(NHISTORY,101)RATIO
F 101 FORMAT('  Cfuge 3 Design Spec',/,'  Fraction Solids',g12.5)
    SPEC  RATIO  TO 0.30
    TOL-SPEC 0.01
    VARY BLOCK-VAR BLOCK=S601 SENTENCE=FRAC VARIABLE=FRACS   &
                   ID1=MIXED ID2=601 ELEMENT=1
    LIMITS 0.05 0.40
;
DESIGN-SPEC CT-T610
    DEFINE SOL625 STREAM-VAR STREAM=625 SUBSTREAM=CISOLID &
                  VARIABLE=MASS-FLOW
    DEFINE WAT625 STREAM-VAR STREAM=625 SUBSTREAM=MIXED   &
                  VARIABLE=MASS-FLOW
;   The spec of 0.05 is just a guess -- MR 24 Apr 97
    SPEC"SOL625/(SOL625+WAT625)" TO "0.05"
    TOL-SPEC"0.001"
    VARY BLOCK-VAR BLOCK=T610 SENTENCE=FRAC VARIABLE=FRAC &
         ID1=MIXED ID2=625
    LIMITS "0.0" "1.0"
;
DESIGN-SPEC CT-S614
    DEFINE SOL623 STREAM-VAR STREAM=623 SUBSTREAM=CISOLID &
                  VARIABLE=MASS-FLOW
    DEFINE WAT623 STREAM-VAR STREAM=623 SUBSTREAM=MIXED   &
                  VARIABLE=MASS-FLOW
;   The spec of 0.30 is just a guess -- MR 24 Apr 97
    SPEC"SOL623/(SOL623+WAT623)" TO "0.3"
    TOL-SPEC"0.001"
    VARY BLOCK-VAR BLOCK=S614 SENTENCE=FRAC VARIABLE=FRAC &
         ID1=MIXED ID2=623
    LIMITS "0.0" "1.0"
;
;-------------------------------------------------------
;                DIGESTOR FORTRAN BLOCKS - AREA 6000
;-------------------------------------------------------
```

```
;
;  This FORTRAN Block works with the design-spec CFUGE3S to make
;  vary the splits of all of the following components the same
;  as water (F1).  Water split is being varied by CFUGE3S.  CSL Split
;  is not controlled by this block.
FORTRAN CFUGESLD
    DEFINE F1      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=1
    DEFINE F2      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=2
    DEFINE F3      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=3
    DEFINE F4      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=4
    DEFINE F5      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=5
    DEFINE F6      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=6
    DEFINE F7      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=7
    DEFINE F8      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=8
    DEFINE F9      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=9
    DEFINE F10     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=10
    DEFINE F11     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=11
    DEFINE F12     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=12
    DEFINE F15     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=15
    DEFINE F16     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=16
    DEFINE F17     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=17
    DEFINE F18     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=18
    DEFINE F19     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=19
    DEFINE F20     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=20
    DEFINE F21     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=21
    DEFINE F23     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=23
    DEFINE F25     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=25
    DEFINE F26     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=26
    DEFINE F27     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=27
    DEFINE F28     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=28
    DEFINE F29     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=29
    DEFINE F30     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=30
    DEFINE F31     BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                   VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=31
```

```
    DEFINE F32      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                    VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=32
    DEFINE F33      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                    VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=33
    DEFINE F34      BLOCK-VAR BLOCK=S601 SENTENCE=FRAC   &
                    VARIABLE=FRACS ID1=MIXED ID2=601 ELEMENT=34

;
F     F2=F1
F     F3=F1
F     F4=F1
F     F5=F1
F     F6=F1
F     F7=F1
F     F8=F1
F     F9=F1
F     F10=F1
F     F11=F1
F     F12=F1
F     F15=F1
F     F16=F1
F     F17=F1
F     F18=F1
F     F19=F1
F     F20=F1
F     F21=F1
F     F23=F1
F     F25=F1
F     F26=F1
F     F27=F1
F     F28=F1
F     F29=F1
F     F30=F1
F     F31=F1
F     F32=F1
F     F33=F1
F     F34=F1
;
    EXECUTE BEFORE BLOCK S601
;
;
FORTRAN AERAIR
F       COMMON/ WWLOD2/ COD2, BOD2, CODDY2, BODDY2
    DEFINE AIR STREAM-VAR STREAM=626 SUBSTREAM=MIXED  &
        VARIABLE=MOLE-FLOW
C THE AIR REQUIREMENT IS 50% ABOVE  THEORETICAL (J. RUOCCO)
C
F      XO2 = 2.5*COD2
F      AIR=XO2/0.21
    EXECUTE BEFORE BLOCK T608
;
FORTRAN RECYCLE
; BLOCK TO CALCULATE THE AMOUNT OF RECYCLE NEEDED AND INCOMING
; FRESH WATER
;
; DEFINE VARIABLES FOR FRESH WATER AND PROCESS RECYCLE WATER
     DEFINE FWAT STREAM-VAR STREAM=604 SUBSTREAM=MIXED VARIABLE=MASS-FLOW
     DEFINE RWAT STREAM-VAR STREAM=603 SUBSTREAM=MIXED VARIABLE=MASS-FLOW
;     DEFINE RWT2 STREAM-VAR STREAM=534 SUBSTREAM=MIXED VARIABLE=MASS-FLOW
     DEFINE RWT3 STREAM-VAR STREAM=516 SUBSTREAM=MIXED VARIABLE=MASS-FLOW
```

```
;;
;; DEFINE VARIABLES FOR RECYCLE WATER STREAM #1.  THIS STREAM
;; CONTROLS THE SOLIDS CONCENTRATION IN THE IMPREGNATOR.
;;
;     DEFINE CI1 STREAM-VAR STREAM=214A SUBSTREAM=CISOLID              &
;                VARIABLE=MASS-FLOW
;     DEFINE STV1 STREAM-VAR STREAM=215 SUBSTREAM=MIXED                &
;                 VARIABLE=MASS-FLOW
;     DEFINE STV2 STREAM-VAR STREAM=216 SUBSTREAM=MIXED                &
;                 VARIABLE=MASS-FLOW
;     DEFINE ACV1 STREAM-VAR STREAM=212 SUBSTREAM=MIXED                &
;                 VARIABLE=MASS-FLOW
;     DEFINE FDV1 STREAM-VAR STREAM=101 SUBSTREAM=MIXED                &
;                 VARIABLE=MASS-FLOW
;     DEFINE RI1 STREAM-VAR STREAM=211 SUBSTREAM=CISOLID               &
;                VARIABLE=MASS-FLOW
;
; DEFINE VARIABLES FOR RECYCLE WATER STREAM #2 (Stream. 219).  THIS
; STREAM CONTROLS THE SOLIDS CONCENTRATION to fermentation
;
    DEFINE RV2 STREAM-VAR STREAM=219 SUBSTREAM=MIXED                  &
               VARIABLE=MASS-FLOW
    DEFINE RI2 STREAM-VAR STREAM=219 SUBSTREAM=CISOLID                &
               VARIABLE=MASS-FLOW
    DEFINE RGLU MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=GLUCOSE
    DEFINE RXYE MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=XYLOSE
    DEFINE RSSL MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=SOLSLDS
    DEFINE RARS MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=ARABINOS
    DEFINE RGAS MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=GALACTOS
    DEFINE RMAS MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=MANNOSE
    DEFINE RCSL MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=CSL
    DEFINE RCNT MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=CNUTR
    DEFINE RWNT MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=WNUTR
    DEFINE RGLO MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=GLUCOLIG
    DEFINE RCLB MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=CELLOB
    DEFINE RXYO MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=XYLOLIG
    DEFINE RMAO MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=MANOLIG
    DEFINE RGAO MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=GALAOLIG
    DEFINE RARO MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=ARABOLIG
    DEFINE RACO MASS-FLOW STREAM=219 SUBSTREAM=MIXED                   &
                COMPONENT=ACETOLIG
;
; DEFINE THE COMPONENTS OF STREAM 232 (Diluted Hydrolysate)
;
    DEFINE HF1 STREAM-VAR STREAM=232 SUBSTREAM=MIXED                  &
```

```
                VARIABLE=MASS-FLOW
     DEFINE HS1 STREAM-VAR STREAM=232 SUBSTREAM=CISOLID                &
                VARIABLE=MASS-FLOW
     DEFINE HGLU MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=GLUCOSE
     DEFINE HXYE MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=XYLOSE
     DEFINE HSSL MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=SOLSLDS
     DEFINE HARS MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=ARABINOS
     DEFINE HGAS MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=GALACTOS
     DEFINE HMAS MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=MANNOSE
     DEFINE HCSL MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=CSL
     DEFINE HCNT MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=CNUTR
     DEFINE HWNT MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=WNUTR
     DEFINE HGLO MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=GLUCOLIG
     DEFINE HCLB MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=CELLOB
     DEFINE HXYO MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=XYLOLIG
     DEFINE HMAO MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=MANOLIG
     DEFINE HGAO MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=GALAOLIG
     DEFINE HARO MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=ARABOLIG
     DEFINE HACO MASS-FLOW STREAM=232 SUBSTREAM=MIXED                    &
                 COMPONENT=ACETOLIG
;
; DEFINE THE COMPONENTS OF STREAM 401 (Feed to Cellulase Production)
;
;     DEFINE CFF1 STREAM-VAR STREAM=401 SUBSTREAM=MIXED                &
;                 VARIABLE=MASS-FLOW
;     DEFINE CFS1 STREAM-VAR STREAM=401 SUBSTREAM=CISOLID              &
;                 VARIABLE=MASS-FLOW
;     DEFINE CFGLU MASS-FLOW STREAM=401 SUBSTREAM=MIXED                  &
;                  COMPONENT=GLUCOSE
;     DEFINE CFXYE MASS-FLOW STREAM=401 SUBSTREAM=MIXED                  &
;                  COMPONENT=XYLOSE
;     DEFINE CFSSL MASS-FLOW STREAM=401 SUBSTREAM=MIXED                  &
;                  COMPONENT=SOLSLDS
;     DEFINE CFARS MASS-FLOW STREAM=401 SUBSTREAM=MIXED                  &
;                  COMPONENT=ARABINOS
;     DEFINE CFGAS MASS-FLOW STREAM=401 SUBSTREAM=MIXED                  &
;                  COMPONENT=GALACTOS
;     DEFINE CFMAS MASS-FLOW STREAM=401 SUBSTREAM=MIXED                  &
;                  COMPONENT=MANNOSE
;     DEFINE CFCSL MASS-FLOW STREAM=401 SUBSTREAM=MIXED                  &
;                  COMPONENT=CSL
;     DEFINE CFCNT MASS-FLOW STREAM=401 SUBSTREAM=MIXED                  &
;                  COMPONENT=CNUTR
;     DEFINE CFWNT MASS-FLOW STREAM=401 SUBSTREAM=MIXED                  &
;                  COMPONENT=WNUTR
```

```
;      DEFINE CFGLO MASS-FLOW STREAM=401 SUBSTREAM=MIXED                   &
;                   COMPONENT=GLUCOLIG
;      DEFINE CFCLB MASS-FLOW STREAM=401 SUBSTREAM=MIXED                   &
;                   COMPONENT=CELLOB
;      DEFINE CFXYO MASS-FLOW STREAM=401 SUBSTREAM=MIXED                   &
;                   COMPONENT=XYLOLIG
;      DEFINE CFMAO MASS-FLOW STREAM=401 SUBSTREAM=MIXED                   &
;                   COMPONENT=MANOLIG
;      DEFINE CFGAO MASS-FLOW STREAM=401 SUBSTREAM=MIXED                   &
;                   COMPONENT=GALAOLIG
;      DEFINE CFARO MASS-FLOW STREAM=401 SUBSTREAM=MIXED                   &
;                   COMPONENT=ARABOLIG
;      DEFINE CFACO MASS-FLOW STREAM=401 SUBSTREAM=MIXED                   &
;                   COMPONENT=ACETOLIG
;
; DEFINE THE COMPONENTS OF STREAM 422 (Cellulase to SSCF Production)
;
     DEFINE CPF1 STREAM-VAR STREAM=422 SUBSTREAM=MIXED                  &
                 VARIABLE=MASS-FLOW
     DEFINE CPS1 STREAM-VAR STREAM=422 SUBSTREAM=CISOLID                &
                 VARIABLE=MASS-FLOW
     DEFINE CPGLU MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=GLUCOSE
     DEFINE CPXYE MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=XYLOSE
     DEFINE CPSSL MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=SOLSLDS
     DEFINE CPARS MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=ARABINOS
     DEFINE CPGAS MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=GALACTOS
     DEFINE CPMAS MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=MANNOSE
     DEFINE CPCSL MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=CSL
     DEFINE CPCNT MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=CNUTR
     DEFINE CPWNT MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=WNUTR
     DEFINE CPGLO MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=GLUCOLIG
     DEFINE CPCLB MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=CELLOB
     DEFINE CPXYO MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=XYLOLIG
     DEFINE CPMAO MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=MANOLIG
     DEFINE CPGAO MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=GALAOLIG
     DEFINE CPARO MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=ARABOLIG
     DEFINE CPACO MASS-FLOW STREAM=422 SUBSTREAM=MIXED                   &
                  COMPONENT=ACETOLIG
;
; DEFINE THE COMPONENTS OF STREAM 311 (CSL to SSCF Production)
;
     DEFINE CLF1 STREAM-VAR STREAM=311 SUBSTREAM=MIXED                  &
                 VARIABLE=MASS-FLOW
     DEFINE CLS1 STREAM-VAR STREAM=311 SUBSTREAM=CISOLID                &
                 VARIABLE=MASS-FLOW
```

```
    DEFINE CLGLU MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=GLUCOSE
    DEFINE CLXYE MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=XYLOSE
    DEFINE CLSSL MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=SOLSLDS
    DEFINE CLARS MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=ARABINOS
    DEFINE CLGAS MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=GALACTOS
    DEFINE CLMAS MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=MANNOSE
    DEFINE CLCSL MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=CSL
    DEFINE CLCNT MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=CNUTR
    DEFINE CLWNT MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=WNUTR
    DEFINE CLGLO MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=GLUCOLIG
    DEFINE CLCLB MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=CELLOB
    DEFINE CLXYO MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=XYLOLIG
    DEFINE CLMAO MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=MANOLIG
    DEFINE CLGAO MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=GALAOLIG
    DEFINE CLARO MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=ARABOLIG
    DEFINE CLACO MASS-FLOW STREAM=311 SUBSTREAM=MIXED                    &
                 COMPONENT=ACETOLIG
;
; DEFINE THE COMPONENTS OF STREAM 303 (Feed to SSCF Seed)
;
    DEFINE SFF1 STREAM-VAR STREAM=303 SUBSTREAM=MIXED                   &
                VARIABLE=MASS-FLOW
    DEFINE SFS1 STREAM-VAR STREAM=303 SUBSTREAM=CISOLID                 &
                VARIABLE=MASS-FLOW
    DEFINE SFGLU MASS-FLOW STREAM=303 SUBSTREAM=MIXED                    &
                 COMPONENT=GLUCOSE
    DEFINE SFXYE MASS-FLOW STREAM=303 SUBSTREAM=MIXED                    &
                 COMPONENT=XYLOSE
    DEFINE SFSSL MASS-FLOW STREAM=303 SUBSTREAM=MIXED                    &
                 COMPONENT=SOLSLDS
    DEFINE SFARS MASS-FLOW STREAM=303 SUBSTREAM=MIXED                    &
                 COMPONENT=ARABINOS
    DEFINE SFGAS MASS-FLOW STREAM=303 SUBSTREAM=MIXED                    &
                 COMPONENT=GALACTOS
    DEFINE SFMAS MASS-FLOW STREAM=303 SUBSTREAM=MIXED                    &
                 COMPONENT=MANNOSE
    DEFINE SFCSL MASS-FLOW STREAM=303 SUBSTREAM=MIXED                    &
                 COMPONENT=CSL
    DEFINE SFCNT MASS-FLOW STREAM=303 SUBSTREAM=MIXED                    &
                 COMPONENT=CNUTR
    DEFINE SFWNT MASS-FLOW STREAM=303 SUBSTREAM=MIXED                    &
                 COMPONENT=WNUTR
    DEFINE SFGLO MASS-FLOW STREAM=303 SUBSTREAM=MIXED                    &
                 COMPONENT=GLUCOLIG
    DEFINE SFCLB MASS-FLOW STREAM=303 SUBSTREAM=MIXED                    &
```

```
                 COMPONENT=CELLOB
    DEFINE SFXYO MASS-FLOW STREAM=303 SUBSTREAM=MIXED                   &
                 COMPONENT=XYLOLIG
    DEFINE SFMAO MASS-FLOW STREAM=303 SUBSTREAM=MIXED                   &
                 COMPONENT=MANOLIG
    DEFINE SFGAO MASS-FLOW STREAM=303 SUBSTREAM=MIXED                   &
                 COMPONENT=GALAOLIG
    DEFINE SFARO MASS-FLOW STREAM=303 SUBSTREAM=MIXED                   &
                 COMPONENT=ARABOLIG
    DEFINE SFACO MASS-FLOW STREAM=303 SUBSTREAM=MIXED                   &
                 COMPONENT=ACETOLIG
;
; DEFINE THE COMPONENTS OF STREAM 304 (SSCF Seed to Production)
;
    DEFINE SPF1 STREAM-VAR STREAM=304 SUBSTREAM=MIXED                  &
                VARIABLE=MASS-FLOW
    DEFINE SPS1 STREAM-VAR STREAM=304 SUBSTREAM=CISOLID                &
                VARIABLE=MASS-FLOW
    DEFINE SPGLU MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=GLUCOSE
    DEFINE SPXYE MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=XYLOSE
    DEFINE SPSSL MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=SOLSLDS
    DEFINE SPARS MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=ARABINOS
    DEFINE SPGAS MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=GALACTOS
    DEFINE SPMAS MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=MANNOSE
    DEFINE SPCSL MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=CSL
    DEFINE SPCNT MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=CNUTR
    DEFINE SPWNT MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=WNUTR
    DEFINE SPGLO MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=GLUCOLIG
    DEFINE SPCLB MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=CELLOB
    DEFINE SPXYO MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=XYLOLIG
    DEFINE SPMAO MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=MANOLIG
    DEFINE SPGAO MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=GALAOLIG
    DEFINE SPARO MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=ARABOLIG
    DEFINE SPACO MASS-FLOW STREAM=304 SUBSTREAM=MIXED                   &
                 COMPONENT=ACETOLIG

; DEFINE VARIABLES FOR RECYCLE WATER STREAM #3.  THIS STREAM
; CONTROLS THE XYLOSE AND CELLULOSE CONCENTRATIONS IN 431.
; CURRENTLY, THIS IS SET TO 1%.
;
    DEFINE CV3 STREAM-VAR STREAM=403 SUBSTREAM=MIXED                   &
               VARIABLE=MASS-FLOW
    DEFINE CI3 STREAM-VAR STREAM=403 SUBSTREAM=CISOLID                 &
               VARIABLE=MASS-FLOW
    DEFINE RI3 STREAM-VAR STREAM=430 SUBSTREAM=CISOLID                 &
```

```
                VARIABLE=MASS-FLOW
     DEFINE ST3X MASS-FLOW STREAM=403 SUBSTREAM=MIXED                  &
                 COMPONENT=XYLOSE
     DEFINE ST3C MASS-FLOW STREAM=403 SUBSTREAM=CISOLID                &
                 COMPONENT=CELLULOSE
     DEFINE R3X MASS-FLOW STREAM=430 SUBSTREAM=MIXED                   &
                COMPONENT=XYLOSE
     DEFINE R3C MASS-FLOW STREAM=430 SUBSTREAM=CISOLID                 &
                COMPONENT=CELLULOSE
;
; DEFINE VARIABLES FOR RECYCLE WATER STREAM #4.  THIS STREAM
; CONTROLS THE CELLULOSE CONCENTRATION IN 412A.
; CURRENTLY, THIS IS SET TO 4%.
;
     DEFINE CV4 STREAM-VAR STREAM=410 SUBSTREAM=MIXED                  &
                VARIABLE=MASS-FLOW
     DEFINE CI4 STREAM-VAR STREAM=410 SUBSTREAM=CISOLID                &
                VARIABLE=MASS-FLOW
     DEFINE RI4 STREAM-VAR STREAM=411 SUBSTREAM=CISOLID                &
                VARIABLE=MASS-FLOW
     DEFINE ST4C MASS-FLOW STREAM=410 SUBSTREAM=CISOLID                &
                 COMPONENT=CELLULOSE
     DEFINE R4C MASS-FLOW STREAM=411 SUBSTREAM=CISOLID                 &
                COMPONENT=CELLULOSE
;
; DEFINE SPLIT VARIABLES IN THE RECYCLE WATER SPLITTER.
;
;     DEFINE F1 BLOCK-VAR BLOCK=RWSPLT SENT=FRAC &
;               VARIABLE=FRAC ID1=211
     DEFINE F2 BLOCK-VAR BLOCK=RWSPLT SENT=FRAC &
               VARIABLE=FRAC ID1=219
     DEFINE F3 BLOCK-VAR BLOCK=RWSPLT SENT=FRAC &
               VARIABLE=FRAC ID1=430

;
; DEFINE THE COMPONENTS OF STREAM 220 (Out of Pre Hydrolysis
;
     DEFINE HP1 STREAM-VAR STREAM=220 SUBSTREAM=MIXED                  &
                VARIABLE=MASS-FLOW
     DEFINE HPS1 STREAM-VAR STREAM=220 SUBSTREAM=CISOLID                &
                 VARIABLE=MASS-FLOW
;
;FORTRAN STATEMENTS
C  CSLCONC is the solids concentration of CSL
c     CSLCONC=0.5
;c
;c  CONC1: Solids Concentration in Impregnator Feed, Stream 214A
;c
;F     CONC1 = 0.3091
;F     CV1 = ((1.-CONC1)/CONC1) * CI1 - STV1 - STV2
;;c
;c  AV1 Recycle water flow (Stream 211)
;c
;F     AV1 = CV1 - (ACV1 + FDV1)
;c
c  AV2:   Recycle water flow (Stream 219)
c  CONC2: Total Solids Conc going to Fermentation (Stream 232)
c         (Includes sugars + solslds)
C  SLD232:  Total Solids in Stream 232
C  SLD219:  Total Solids in Stream 219
```

```
C  TTL232:  Total Flow in Stream 232
C  TTL219:  Total Flow in Stream 219
C  CNC219:  Total Solids Conc in Stream 219
C  OTHSLD:  Total Other Solids
C  OTHTTL:  Total Other Flow
c
c  CONC2 is the desired SSCF effective solids concentration
F     CONC2 = 0.2
c  OLG calcs are the oligomer flows in each stream
c  SLD calcs are the total solids in each stream
F     OLG232 = HGLO + HCLB + HXYO + HMAO + HGAO + HARO + HACO
F     SLD232 = HS1 + HGLU + HXYE + HSSL + HARS + HGAS + HMAS +
F    1         (HCSL*CSLCONC) + HCNT + HWNT + OLG232
F     OLG219 = RGLO + RCLB + RXYO + RMAO + RGAO + RARO + RACO
F     SLD219 = RI2 + RGLU + RXYE + RSSL + RARS + RGAS + RMAS +
F    1         (RCLS*CSLCONC) + RCNT + RWNT + OLG219
F     OLG401 = CFGLO + CFCLB + CFXYO + CFMAO + CFGAO + CFARO + CFACO
F     SLD401 = CFI2 + CFGLU + CFXYE + CFSSL + CFARS + CFGAS + CFMAS +
F    1         (CFCLS*CSLCONC) + CFCNT + CFWNT + OLG401
F     OLG422 = CPGLO + CPCLB + CPXYO + CPMAO + CPGAO + CPARO + CPACO
F     SLD422 = CPI2 + CPGLU + CPXYE + CPSSL + CPARS + CPGAS + CPMAS +
F    1         (CPCLS*CSLCONC) + CPCNT + CPWNT + OLG422
F     OLG311 = CLGLO + CLCLB + CLXYO + CLMAO + CLGAO + CLARO + CLACO
F     SLD311 = CLI2 + CLGLU + CLXYE + CLSSL + CLARS + CLGAS + CLMAS +
F    1         (CLCLS*CSLCONC) + CLCNT + CLWNT + OLG311
F     OLG303 = SFGLO + SFCLB + SFXYO + SFMAO + SFGAO + SFARO + SFACO
F     SLD303 = SFI2 + SFGLU + SFXYE + SFSSL + SFARS + SFGAS + SFMAS +
F    1         (SFCLS*CSLCONC) + SFCNT + SFWNT + OLG303
F     OLG304 = SPGLO + SPCLB + SPXYO + SPMAO + SPGAO + SPARO + SPACO
F     SLD304 = SPI2 + SPGLU + SPXYE + SPSSL + SPARS + SPGAS + SPMAS +
F    1         (SPCLS*CSLCONC) + SPCNT + SPWNT + OLG304
c  TTL calc are the total flows of each stream
F     TTL232 = HF1 + HS1
F     TTL219 = RV2 + RI2
F     TTL401 = CFF1 + CFS1
F     TTL422 = CPF1 + CPS1
F     TTL311 = CLF1 + CLS1
F     TTL303 = SFF1 + SFS1
F     TTL304 = SPF1 + SPS1
F     CNC219 = SLD219 / TTL219
;F     OTHSLD = SLD232 - SLD219 +SLD422+SLD311-SLD303+SLD304
F     OTHSLD = SLD232 - SLD219 - SLD401 + SLD422 + SLD311 - SLD303
F    1       + SLD304
;F     OTHTTL = TTL232 - TTL219 +TTL422+TTL311-TTL303+TTL304
F     OTHTTL = TTL232 - TTL219 - TTL401 + TTL422 + TTL311 - TTL303
F    1       + TTL304
F     CAL219 = ((CONC2 * OTHTTL) - OTHSLD) / (CNC219 - CONC2)
F     AV2 = CAL219 - RI2
c
c  CONC3: Cellulose + Xylose concentration in Stream 431
c  AV3: Recycle Flow Stream 430
c
F     CONC3 = 0.04
F     AV3 = ((ST3X + ST3C + R3X + R3C) / CONC3)
F    1    - (CI3 +  CV3 + RI3)
c
c  CONC4: Cellulose + Xyloxe in Stream 412A
c  AV4: Recycle Flow Stream 430
c
F     CONC4 = 0.04
```

```
F     AV4 = ((ST4C + R4C) / CONC4) -(CI4 + CV4 + RI4)
c
c  Recalc Concentrations and write to the history file
c
;F     CNC1a = CI1 / (CV1 + CI1 + STV1)
;F     CNC1  = CI1 / (CV1 + CI1 + STV1 + STV2)
;F     CNC1b = HPS1 / (HP1 + HPS1)
;F     CNC2  = (SLD232 +SLD422+SLD311-SLD303+SLD304)
;F    1      / (TTL232 +TTL422+TTL311-TTL303+TTL304)
;F     CNC2b = (RI2 +CPS1+CLS1-SFS1+SPS1)
;F    1      / (TTL232 +TTL422+TTL311-TTL303+TTL304)
F     CNC2  = (SLD232 - SLD401 + SLD422 + SLD311 - SLD303 + SLD304)
F    1      / (TTL232 - TTL401 + TTL422 + TTL311 - TTL303 + TTL304)
F     CNC2b = (RI2 - CFS1 + CPS1 + CLS1 - SFS1 + SPS1)
F    1      / (TTL232 - TTL401 + TTL422 + TTL311 - TTL303 + TTL304)
F     CNC3 = (ST3X + ST3C + R3X + R3C)
F    1     / (CI3 + CV3 + RI3 + AV3)
F     CNC4 = (ST4C + R4C) / (CI4 + CV4 + RI4 + AV4)
c
F     WRITE(NHSTRY,101)CNC2,CNC3,CNC4,CNC2b
F 101 FORMAT(' RECYCLE Fortran Block Results',/,
F    1       ' Specified Concentrations',/,
F    3       ' SSCF Effective Solids Conc:                 ',g12.5,/,
F    4       ' Cellulase Seed Feed Cellulose+Xylose (431): ',g12.5,/,
F    5       ' Cellulase Ferm Cellulose Conc (412A):       ',g12.5,/,/,
F    6       ' Other Concentrations',/,
F    5       ' SSCF Insoluble Solids Conc:                 ',g12.5)
c
c  Calculate Splits for Block RWSPLT
c
;F     F1=AV1/(AV1+AV2+AV3+AV4)
F     F2=AV2/(AV2+AV3+AV4)
F     F3=AV3/(AV2+AV3+AV4)
F     F4=1-F2-F3
c
c  Calculate Make-up Water, Stream 604
c
F     RWTAV = RWAT + RWT3
F     FWAT= AV2 + RI2 + AV3 + RI3 + AV4 + RI4 - RWTAV
      EXECUTE BEFORE FWMIX
;
FORTRAN RECCOND
;
; DEFINE VARIABLES FOR RECYCLE WATER STREAM #1.  THIS STREAM
; CONTROLS THE SOLIDS CONCENTRATION IN THE IMPREGNATOR.
;
     DEFINE CI1 STREAM-VAR STREAM=214A SUBSTREAM=CISOLID               &
                VARIABLE=MASS-FLOW
     DEFINE STV1 STREAM-VAR STREAM=215 SUBSTREAM=MIXED                 &
                 VARIABLE=MASS-FLOW
     DEFINE STV2 STREAM-VAR STREAM=216 SUBSTREAM=MIXED                 &
                 VARIABLE=MASS-FLOW
     DEFINE ACV1 STREAM-VAR STREAM=212 SUBSTREAM=MIXED                 &
                 VARIABLE=MASS-FLOW
     DEFINE FDV1 STREAM-VAR STREAM=101 SUBSTREAM=MIXED                 &
                 VARIABLE=MASS-FLOW
     DEFINE AV1  BLOCK-VAR BLOCK=E501SPT SENTENCE=MASS-FLOW           &
                  VARIABLE=FLOW ID1=211
c
c  CONC1: Solids Concentration in Impregnator Feed, Stream 214A
```

```
c
F      CONC1 = 0.3091
F      CV1 = ((1.-CONC1)/CONC1) * CI1 - STV1 - STV2
c
c  AV1 Recycle water flow (Stream 211)
c
F      AV1 = CV1 - (ACV1 + FDV1)
c
F      CNC1a = CI1 / (CV1 + CI1 + STV1)
F      CNC1  = CI1 / (CV1 + CI1 + STV1 + STV2)
    READ-VARS CI1 STV1 STV2 ACV1 FDV1
    WRITE-VARS AV1
;     EXECUTE BEFORE E501MIX
;
FORTRAN CODCALC1
C Calculates the incomming COD
F        COMMON/ WWLOAD/ CODTOT, BODTOT, CODDAY, BODDAY
    DEFINE GLUC MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=GLUCOSE
    DEFINE XYLO MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=XYLOSE
    DEFINE UNKN MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=UNKNOWN
    DEFINE SOLS MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=SOLSLDS
    DEFINE ARAB MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=ARABINOS
    DEFINE GALA MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=GALACTOS
    DEFINE XMANS MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=MANNOSE
    DEFINE GLUO MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=GLUCOLIG
    DEFINE CELB MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=CELLOB
    DEFINE XYLG MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=XYLOLIG
    DEFINE XMANO MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=MANOLIG
    DEFINE GALO MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=GALAOLIG
    DEFINE ARAO MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=ARABOLIG
    DEFINE ACEO MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=ACETOLIG
    DEFINE XYLL MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=XYLITOL
    DEFINE ETOH MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=ETHANOL
    DEFINE FURF MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=FURFURAL
    DEFINE XHMF MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=HMF
    DEFINE CH4 MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=CH4
    DEFINE XLACI MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=LACID
    DEFINE AACI MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=AACID
    DEFINE GLYC MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
```

```
        COMPONENT=GLYCEROL
    DEFINE SUCC MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=SUCCACID
    DEFINE DENA MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=DENAT
    DEFINE XOIL MASS-FLOW STREAM=613 SUBSTREAM=MIXED  &
        COMPONENT=OIL
    DEFINE XNNH4 MASS-FLOW STREAM=613 SUBSTREAM=CISOLID &
        COMPONENT=NH4ACET
C
C SET THE COD FOR COMPONENTS (KG O2/KG COMPONENT)
C THE COD VALUES ARE THE THEORETICAL O2 REQUIRED FOR COMBUSTION, BUT
C ONLY FOR SOLUBLE COMPONENTS.  INSOLUBLE COMPONENTS ARE ASSUMED TO
C BE NON-REACTIVE AND ARE NOT CONTAINED IN THE CALCULATION.
C
C  SOLUBLE C-CONTAINING COMPOUNDS
F      CGLUC = 1.07
F      CXYLO = 1.07
F      CUNKN = 1.07
F      CSOLS = 0.71
F      CETOH = 2.09
F      CARAB = 1.07
F      CGALA = 1.07
F      CMANS = 1.07
F      CGLUO = 1.07
F      CCELB = 1.07
F      CXYLG = 1.07
F      CMANO = 1.07
F      CGALO = 1.07
F      CARAO = 1.07
F      CXYLL = 1.22
F      CFURF = 1.67
F      CHMF  = 1.52
F      CCH4  = 4.0
F      CLACI = 1.07
F      CAACI = 1.07
F      CGLYC = 1.22
F      CSUCC = 0.95
F      CDENA = 3.52
F      COIL  = 2.89
F      CACEO = 1.07
F      CNNH4 = 1.143
C
C
C  CALCULATE HOURLY COD LOADINGS (KG/HR)
C
F     CODTOT = GLUC*CGLUC + XYLO*CXYLO + UNKN*CUNKN + SOLS*CSOLS +
F    1         GALA*CGALA + XMANS*CMANS + ARAB*CARAB + GLUO*CGLUO +
F    2         CELB*CCELB + XYLG*CXYLG + XMANO*CMANO + GALO*CGALO +
F    3         ARAO*CARAO + XYLL*CXYLL + ETOH*CETOH + FURF*CFURF  +
F    4         XHMF*CHMF   + CH4*CCH4   + XACI*CLACI + AACI*CAACI +
F    5         GLYC*CGLYC + SUCC*CSUCC + DENA*CDENA + XOIL*COIL   +
F    6         ACEO*CACEO  + CNNH4*XNNH4
C
C
C  CALCULATE HOURLY BOD LOADINGS (KG/HR)
C
F      BODCOD = 0.70
C BODCOD IS THE BOD/COD RATIO AND WAS PROVIDED BY J. RUOCCO 7/29/98
C THIS VALUE IS WITHIN THE RANGE (0.45-0.78) PROVIDED IN PERRY'S
```

```
C 7TH EDITION, PG. 25-62.
C
F       BODTOT= BODCOD*CODTOT
C
C
C  CALCULATE DAILY BOD AND COD LOADINGS (LB/DAY)
C
F       CODDAY = CODTOT*2.205*24.
F       BODDAY = BODTOT*2.205*24.
C
C 2.205 IS LB/KG AND 24 HR/DAY TO CONVERT KG/HR TO LB/DAY
C
C    WRITE ANSWERS TO THE HISTORY FILE
C
F      WRITE(NHSTRY,*)'CODTOT, BODTOT= ',CODTOT, BODTOT
F      WRITE(NHSTRY,*)'CODDAY, BODDAY= ',CODDAY, BODDAY
C
    READ-VARS GLUC

FORTRAN CODCALC2
C Calculates COD after ANEROBIC and before AEROBIC
F        COMMON/ WWLOD2/ COD2, BOD2, CODDY2, BODDY2
    DEFINE GLUC MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=GLUCOSE
    DEFINE XYLO MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=XYLOSE
    DEFINE UNKN MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=UNKNOWN
    DEFINE SOLS MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=SOLSLDS
    DEFINE ARAB MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=ARABINOS
    DEFINE GALA MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=GALACTOS
    DEFINE XMANS MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=MANNOSE
    DEFINE GLUO MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=GLUCOLIG
    DEFINE CELB MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=CELLOB
    DEFINE XYLG MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=XYLOLIG
    DEFINE XMANO MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=MANOLIG
    DEFINE GALO MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=GALAOLIG
    DEFINE ARAO MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=ARABOLIG
    DEFINE ACEO MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=ACETOLIG
    DEFINE XYLL MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=XYLITOL
    DEFINE ETOH MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=ETHANOL
    DEFINE FURF MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=FURFURAL
    DEFINE XHMF MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=HMF
    DEFINE CH4 MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=CH4
```

```
    DEFINE XLACI MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=LACID
    DEFINE AACI MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=AACID
    DEFINE GLYC MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=GLYCEROL
    DEFINE SUCC MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=SUCCACID
    DEFINE DENA MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
COMPONENT=DENAT
    DEFINE XOIL MASS-FLOW STREAM=618 SUBSTREAM=MIXED  &
        COMPONENT=OIL
    DEFINE XNNH4 MASS-FLOW STREAM=618 SUBSTREAM=CISOLID &
        COMPONENT=NH4ACET
C
C SET THE COD FOR COMPONENTS (KG O2/KG COMPONENT)
C THE COD VALUES ARE THE THEORETICAL O2 REQUIRED FOR COMBUSTION, BUT
C ONLY FOR SOLUBLE COMPONENTS.  INSOLUBLE COMPONENTS ARE ASSUMED TO
C BE NON-REACTIVE AND ARE NOT CONTAINED IN THE CALCULATION.
C
C  SOLUBLE C-CONTAINING COMPOUNDS
F      CGLUC = 1.07
F      CXYLO = 1.07
F      CUNKN = 1.07
F      CSOLS = 0.71
F      CETOH = 2.09
F      CARAB = 1.07
F      CGALA = 1.07
F      CMANS = 1.07
F      CGLUO = 1.07
F      CCELB = 1.07
F      CXYLG = 1.07
F      CMANO = 1.07
F      CGALO = 1.07
F      CARAO = 1.07
F      CXYLL = 1.22
F      CFURF = 1.67
F      CHMF  = 1.52
F      CCH4  = 4.0
F      CLACI = 1.07
F      CAACI = 1.07
F      CGLYC = 1.22
F      CSUCC = 0.95
F      CDENA = 3.52
F      COIL  = 2.89
F      CACEO = 1.07
F      CNNH4 = 1.143
C
C
C  CALCULATE HOURLY COD LOADINGS (KG/HR)
C
F     COD2   = GLUC*CGLUC + XYLO*CXYLO + UNKN*CUNKN + SOLS*CSOLS +
F    1         GALA*CGALA + XMANS*CMANS + ARAB*CARAB + GLUO*CGLUO +
F    2         CELB*CCELB + XYLG*CXYLG + XMANO*CMANO + GALO*CGALO +
F    3         ARAO*CARAO + XYLL*CXYLL + ETOH*CETOH + FURF*CFURF +
F    4         XHMF*CHMF   + CH4*CCH4   + XLACI*CLACI + AACI*CAACI +
F    5         GLYC*CGLYC + SUCC*CSUCC + DENA*CDENA + XOIL*COIL   +
F    6         ACEO*CACEO    + CNNH4*XNNH4
C
C
```

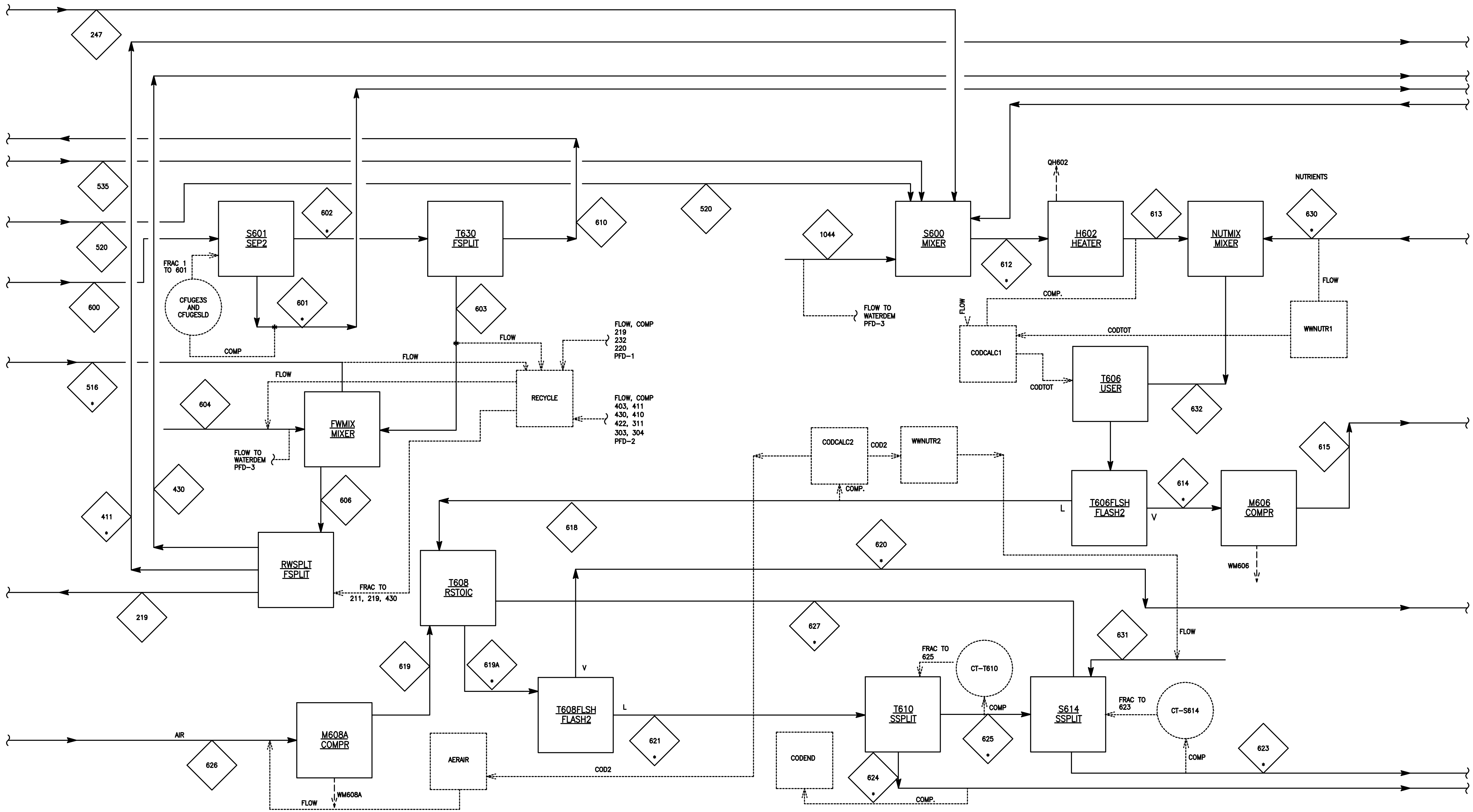
```
C  CALCULATE HOURLY BOD LOADINGS (KG/HR)
C
F       BODCOD = 0.70
C BODCOD IS THE BOD/COD RATIO AND WAS PROVIDED BY J. RUOCCO 7/29/98
C THIS VALUE IS WITHIN THE RANGE (0.45-0.78) PROVIDED IN PERRY'S
C 7TH EDITION, PG. 25-62.
C
F       BOD2 = BODCOD*COD2
C
C
C  CALCULATE DAILY BOD AND COD LOADINGS (LB/DAY)
C
F       CODDY2 = COD2*2.205*24.
F       BODDY2 = BOD2*2.205*24.
C
C 2.205 IS LB/KG AND 24 HR/DAY TO CONVERT KG/HR TO LB/DAY
C
C    WRITE ANSWERS TO THE HISTORY FILE
C
F      WRITE(NHSTRY,*)'COD2, BOD2= ',COD2, BOD2
F      WRITE(NHSTRY,*)'CODDY2, BODDY2= ',CODDY2, BODDY2
C
    READ-VARS GLUC

FORTRAN CODEND
C Calculates the final COD level in the waste water
F        COMMON/ WWLOD3/ COD3, BOD3, CODDY3, BODDY3
    DEFINE GLUC MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=GLUCOSE
    DEFINE XYLO MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=XYLOSE
    DEFINE UNKN MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=UNKNOWN
    DEFINE SOLS MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=SOLSLDS
    DEFINE ARAB MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=ARABINOS
    DEFINE GALA MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=GALACTOS
    DEFINE XMANS MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=MANNOSE
    DEFINE GLUO MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=GLUCOLIG
    DEFINE CELB MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=CELLOB
    DEFINE XYLG MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=XYLOLIG
    DEFINE XMANO MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=MANOLIG
    DEFINE GALO MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=GALAOLIG
    DEFINE ARAO MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=ARABOLIG
    DEFINE ACEO MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=ACETOLIG
    DEFINE XYLL MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=XYLITOL
    DEFINE ETOH MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=ETHANOL
    DEFINE FURF MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
```

```
        COMPONENT=FURFURAL
    DEFINE XHMF MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=HMF
    DEFINE CH4 MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=CH4
    DEFINE XLACI MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=LACID
    DEFINE AACI MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=AACID
    DEFINE GLYC MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=GLYCEROL
    DEFINE SUCC MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=SUCCACID
    DEFINE DENA MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=DENAT
    DEFINE XOIL MASS-FLOW STREAM=624 SUBSTREAM=MIXED  &
        COMPONENT=OIL
    DEFINE XNNH4 MASS-FLOW STREAM=624 SUBSTREAM=CISOLID &
        COMPONENT=NH4ACET
C
C SET THE COD FOR COMPONENTS (KG O2/KG COMPONENT)
C THE COD VALUES ARE THE THEORETICAL O2 REQUIRED FOR COMBUSTION, BUT
C ONLY FOR SOLUBLE COMPONENTS.  INSOLUBLE COMPONENTS ARE ASSUMED TO
C BE NON-REACTIVE AND ARE NOT CONTAINED IN THE CALCULATION.
C
C  SOLUBLE C-CONTAINING COMPOUNDS
F      CGLUC = 1.07
F      CXYLO = 1.07
F      CUNKN = 1.07
F      CSOLS = 0.71
F      CETOH = 2.09
F      CARAB = 1.07
F      CGALA = 1.07
F      CMANS = 1.07
F      CGLUO = 1.07
F      CCELB = 1.07
F      CXYLG = 1.07
F      CMANO = 1.07
F      CGALO = 1.07
F      CARAO = 1.07
F      CXYLL = 1.22
F      CFURF = 1.67
F      CHMF  = 1.52
F      CCH4  = 4.0
F      CLACI = 1.07
F      CAACI = 1.07
F      CGLYC = 1.22
F      CSUCC = 0.95
F      CDENA = 3.52
F      COIL  = 2.89
F      CACEO = 1.07
F      CNNH4 = 1.143
C
C
C  CALCULATE HOURLY COD LOADINGS (KG/HR)
C
F     COD3   = GLUC*CGLUC + XYLO*CXYLO + UNKN*CUNKN + SOLS*CSOLS +
F    1         GALA*CGALA + XMANS*CMANS + ARAB*CARAB + GLUO*CGLUO +
F    2         CELB*CCELB + XYLG*CXYLG + XMANO*CMANO + GALO*CGALO +
F    3         ARAO*CARAO + XYLL*CXYLL + ETOH*CETOH + FURF*CFURF +
```

```
F    4         XHMF*CHMF   + CH4*CCH4   + XLACI*CLACI + AACI*CAACI +
F    5         GLYC*CGLYC + SUCC*CSUCC + DENA*CDENA + XOIL*COIL   +
F    6         ACEO*CACEO    + CNNH4*XNNH4
C
C
C  CALCULATE HOURLY BOD LOADINGS (KG/HR)
C
F      BODCOD = 0.70
C BODCOD IS THE BOD/COD RATIO AND WAS PROVIDED BY J. RUOCCO 7/29/98
C THIS VALUE IS WITHIN THE RANGE (0.45-0.78) PROVIDED IN PERRY'S
C 7TH EDITION, PG. 25-62.
C
F      BOD3 = BODCOD*COD3
C
C
C  CALCULATE DAILY BOD AND COD LOADINGS (LB/DAY)
C
F      CODDY3 = COD3*2.205*24.
F      BODDY3 = BOD3*2.205*24.
C
C 2.205 IS LB/KG AND 24 HR/DAY TO CONVERT KG/HR TO LB/DAY
C
C    WRITE ANSWERS TO THE HISTORY FILE
C
F     WRITE(NHSTRY,*)'COD3, BOD3= ',COD3, BOD3
F     WRITE(NHSTRY,*)'CODDY3, BODDY3= ',CODDY3, BODDY3
C
    READ-VARS GLUC
;
FORTRAN WWNUTR1
F       COMMON/ WWLOAD/ CODTOT, BODTOT, CODDAY, BODDAY
  DEFINE WWTNUT STREAM-VAR STREAM=630 SUBSTREAM=MIXED VARIABLE=MASS-FLOW
C
F      WWTFAC = 3.675E-2
C
C THE AMOUNT OF PHOSPHORIC ACID, UREA, MICRONUTRIENTS AND CAUSTIC
C
F      WWTNUT = WWTFAC*CODTOT
C
    EXECUTE AFTER FORTRAN CODCALC1

FORTRAN WWNUTR2
F       COMMON/ WWLOD2/ COD2, BOD2, CODDY2, BODDY2
  DEFINE WWTNUT STREAM-VAR STREAM=631 SUBSTREAM=MIXED VARIABLE=MASS-FLOW
C
F       WWTFAC = 1.701E-3
C
C WWTFAC IS THE AMOUNT OF POLYMER ADDED LB/LB COD TO THE AEROBIC
C SYSTEM.  IT IS THE AVERAGE VALUE PROVIDED BY J. RUOCCO FOR THE
C 3 SYSTEM DESIGNS (ENZYME, COUNTERCURRENT AND SOFTWOOD)
C POLYMER IS MODELLED AS THE COMPONENT WNUTR
C
F       WWTNUT = WWTFAC*COD2
C
    EXECUTE AFTER FORTRAN CODCALC2


SENSITIVITY MASSFLOW
F     COMMON /FRMSET/ SSFDAY, SSFVES, SSFVOL, SSFWV, PMPFLO
F     COMMON /CLSSET/ CLYLD, CLPROD, CLVES, CLVOL, CLWV
```

```
F     COMMON /WWLOAD/ CODTOT, BODTOT, CODDAY, BODDAY
F     COMMON /WWLOD2/ COD2, BOD2, CODDY2, BODDY2

 DEFINE T612   STREAM-VAR STREAM=612  SUBSTREAM=MIXED VARIABLE=TEMP
 DEFINE T613   STREAM-VAR STREAM=613  SUBSTREAM=MIXED VARIABLE=TEMP
 DEFINE QHX602 INFO-VAR   INFO=HEAT   VARIABLE=DUTY   STREAM=QH602
F     DT=((T612-T1040)-(T613-T1045))/DLOG((T612-T1040)/(T613-T1045))
F     DT = DABS(DT * 1.8)
F     U = 300.
C Convert from cal/s to BTU/hr
F     Q = QHX602 * 14.2869
C Area in square feet
F     A602 = DABS(Q) / (U * DT)
F     WRITE(NHSTRY,106)DT,Q,A602
F 106 FORMAT(' HX Calc Results',/,
F    1       ' DT = ',g12.5,/,
F    2       ' Q  = ',g12.5,/,
F    3       ' A602 = ',g12.5)
;
; WWT Volume Calculations
; THIS CODE CALCULATES THE SIZE OF THE ANAEROBIC DIGESTOR
;  AND THE AEROBIC SYSTEM.
;
      DEFINE TOTANA STREAM-PROP STREAM=632 PROPERTY=MASSFLW
      DEFINE TOTAER STREAM-PROP STREAM=618 PROPERTY=MASSFLW
C
F      ANLOAD = 12.0
F      AELOAD = 0.55
C
C ANLOAD AND AELOAD ARE THE SPACE LOADINGS IN G/L/D FOR THE ANAEROBIC
C AND AEROBIC SYSTEMS, RESPECTIVELY
C BOTH VALUES WERE PROVIDED BY J. RUOCCO
C
F      ANCONC = (CODTOT*1000.)/TOTANA
F      AECONC = (COD2*1000.)/TOTAER
C
C ANCONC AND AECONC ARE THE COD CONCENTRATIONS (G/L)
C THESE CALCULATIONS ASSUME THAT THE STREAMS HAVE THE SAME DENSITY
C AS FOR WATER (1 KG/L).
C
F      ANRT = (ANCONC*24.0)/ANLOAD
F      AERT = (AECONC*24.0)/AELOAD
C
C ANRT AND AERT ARE THE RESIDENCE TIME (H) FOR THE ANAEROBIC AND
C AEROBIC SYSTEMS, RESPECTIVELY
C
F      ANVOL = (TOTANA*ANRT)/3.7854
F      AEVOL = (TOTAER*AERT)/3.7854
C
C ANVOL AND AEVOL ARE THE VOLUMES (GAL) OF THE ANAEROBIC AND AEROBIC
C SYSTEMS, RESPECTIVELY.
C THIS CALCULATION ASSUMES THAT THE STREAMS HAVE THE SAME DENSITY AS
C WATER (1 KG/L).
C
F      WRITE(NHSTRY,*)'ANVOL,AEVOL= ',ANVOL, AEVOL
C Base Case of 4,569,250 Gal of Aerobic Lagoon,
C Requires 16 Lagoon Aerators
C or 285578 Gallons per Aerator
F      IWWTAG = AEVOL /  285578. + 1
F      WRITE(NHSTRY,'('' Num of Aerators: '',g12.5)')IWWTAG
```

ASPEN FLOWSHEET FOR WASTE WATER TREATMENT



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MERRICK

	SCALE	DATE
A		

NREL — NATIONAL RENEWABLE ENERGY LAORATORY
Biotechnology Center For Fuels And Chemicals

A600
ASPEN MODEL R9808B

A-600	BLOCK FLOW	A

Attachment 2
Anaerobic Digestion Subroutine

```
C$ #3 BY: VLP DATE:  26-JUL-18-AUG-1998 DEVELOPED WWT MODEL
C$ #2 BY: ANAVI DATE: 15-NOV-1994 FIXED TYPO INI(NINT)-->INT(NINT)
C$ #1 BY: ANAVI DATE:  1-JUL-1994 NEW FOR USER MODELS
C
C     User Unit Operation Model for an Anaerobic Digestor
C
      SUBROUTINE USRANR (NSIN,    NINFI,  SIN1,   SIN2,    SIN3,
     2                   SIN4,    SINFI,  NSOUT,  NINFO,    SOUT1,
     3                   SOUT2,   SOUT3,  SOUT4,  SINFO,   NSUBS,
     4                   IDXSUB,  ITYPE,  NINT,   INT,     NREAL,
     5                   REAL,    IDS,    NPO,    NBOPST,  NIWORK,
     6                   IWORK,   NWORK,  WORK,   NSIZE,   SIZE,
     7                   INTSIZ,  LD)
C
      IMPLICIT REAL*8 (A-H, O-Z)
C
      DIMENSION SIN1(1), SIN2(1), SIN3(1), SIN4(1), SOUT1(1),
     2          SOUT2(1), SOUT3(1), SOUT4(1), IDXSUB(NSUBS),
     3          ITYPE(NSUBS), INT(NINT), REAL(NREAL), IDS(2,13),
     4          NBOPST(6,NPO), IWORK(NIWORK), WORK(NWORK),
     5          SIZE(NSIZE), INTSIZ(NSIZE)
C
      DIMENSION XAI(99)   ,  IDXAI(99) , XCI(99)  , IDXCI(99) ,
     2          XAO(99)   ,  IDXAO(99) , XCO(99)  , IDXCO(99) ,
     3          IPROG(2)  ,  RETN(228) , IRETN(6) , NFLAGW(11)
C
C
      COMMON /USER/ RMISS,  IMISS,  NGBAL, IPASS, IRESTR,
     2              ICONVG, LMSG,   LPMSG, KFLAG, NHSTRY,
     3              NRPT,   NTRMNL, ISIZE
C
      COMMON /WWLOAD/ CODTOT, BODTOT, CODDAY, BODDAY
C
C
      COMMON /NCOMP/ NCC
C
      COMMON /STWORK/ NRETN, NIRETN, NHXF, NHYF, NWYF,
     1                NSTW, KK1, KK2, KZ1, KZ2,
     2                KAI, KA2, KRET, KRSC, MF,
     3                MX, MX1, MX2, MY, MCS,
     4                MNC, MHXF, MHYF, MWY, MRETN,
     5                MIM, MIC, MIN, MPH, MIRETN,
     6                MKBAS, MKPHAS, MTAPP, MKBASS, MTAPPS,
     7                KEXT, KLNK, KFOUT, KFOUT1, KPHV,
     8                KPHL, KLNGM, MF1, MFST, MSTOIL,
     9                MSTOIS, HV, HL, HL1, HL2,
     *                SV, SL, SL1, SL2, VV,
     1                VL, VL1, VL2, XMWV, XMWL,
     2                XMWL1, XMWL2, HCS, HNCS, SSALT,
     3                VSALT, MSTOI, MLNKL, MLNKS, MLNKIN,
     4                MZWK, MST, MIEXST, MIZWK, HSALT,
     5                FSALT, RATIO, MIPOLY, MRPOLY
C
      COMMON /STWKWK/ LRSTW, LISTW, NCPM, NCPCS, NCPNC, NTRIAL,
     1                IDUM3(2), TCALC, PCALC, VCALC, QCALC, BETCAL,
```

```
     2                RDUM(21)
      COMMON /IDXCC / IDXCC(1)
      COMMON /IDXNCC/ IDXNCC(1)
      COMMON / MW   / XMW(1)
      COMMON /RPTGLB/ IREPFL, ISUB(10)
      COMMON /PLEX/ IB(1)
      DIMENSION B(1)
      EQUIVALENCE (IB(1),B(1))
C
C     VARIABLES IN ARGUMENT LIST
C
C     VAR          I/O     TYPE     DIM      DESCRIPTION
C     ----         ---     ----     ---      ----------------
C     SINFO         O       R                OUTLET WORK STREAM VECTOR
C     SIN1         I/O      R                INLET WASTEWATER STREAM VECTOR
C     SOUT1         O       R                OUTLET STREAM
C     NSUBS         I       I                NUMBER OF SUBSTREAMS
C     IDXSUB        I       I      NSUBS     SUBSTREAM INDEX VECTOR
C     ITYPE         I       I      NSUBS     SUBSTREAM TYPE VECTOR
C     NINT          I       I                LENGTH OF INPUT VECTOR
C     INT          I/O      I      NINT      INPUT INTEGER VECTOR
C     NREAL         I       I                LENGTH OF INPUT REAL VECTOR
C     REAL         I/O      R      NREAL     INPUT REAL VECTOR
C     IDS           I       I      2, 13     ID VECTOR
C     NPO           I       I                NUMBER OF PHYSICAL PROPERTY
OPTIONS
C     NBOPST        I       I      3, NPO    PHYSICAL PROPERTY OPTION SET
POINTER
C     NIWORK        I       I                LENGTH OF INPUT INTEGER WORK
VECTOR
C     IWORK         I       I      NIWORK    INPUT INTEGER WORK VECTOR
C     NWORK         I       I                LENGTH OF INPUT REAL WORK VECTOR
C     WORK          I       R      NWORK     INPUT REAL WORK VECTOR
C     REAL(1)       I       R                COD CONVERSION (FRAC)
C     REAL(2)       I       R                FRACTION CH4 YIELD ON COD
C     REAL(3)       I       R                FRACTION CELL MASS YIELD ON COD
C     REAL(4)       I       R                FRACTION OF CH4 IN OUTLET GAS
C     REAL(5)       I       R                FRACTION OF SOLUBLE SULFATE
C                                            COMPONENTS TO H2S
C
C  *********************************************************************
C  *                                                                   *
C  *         SET COMPONENT INDICES BY COMPONENT ID                     *
C  *                                                                   *
C  *********************************************************************
C
C     THIS ALLOWS MANIPULATION OF THE COMPONENTS BY THE INDICE
C     RATHER THAN THE POSITION IN THE COMPONENT MATRIX.
C
C  *********************************************************************
C  *                                                                   *
C  *         IN-HOUSE DATABASE COMPONENTS                              *
C  *                                                                   *
C  *********************************************************************
      NGLUC = KCCIDC('GLUCOSE')
      NCELU = KCCIDC('CELLULOSE')
      NXYLO = KCCIDC('XYLOSE')
      NXYLA = KCCIDC('XYLAN')
      NLIGN = KCCIDC('LIGNIN')
      NCELL = KCCIDC('CELLULASE')
```

```
      NBIOM = KCCIDC('BIOMASS')
      NZYMO = KCCIDC('ZYMO')
      NUNKN = KCCIDC('UNKNOWN')
      NSOLS = KCCIDC('SOLSLDS')
      NGYPS = KCCIDC('GYPSUM')
C
C  *********************************************************************
C  *                                                                   *
C  *          IN-HOUSE DATABASE ALIASES                                *
C  *                                                                   *
C  *********************************************************************
C
      NARAB = KCCIDC('ARABINOS')
      NGALA = KCCIDC('GALACTOS')
      NMANS = KCCIDC('MANNOSE')
      NARAN = KCCIDC('ARABINAN')
      NMANN = KCCIDC('MANNAN')
      NGALN = KCCIDC('GALACTAN')
      NGLUO = KCCIDC('GLUCOLIG')
      NCELB = KCCIDC('CELLOB')
      NXYLG = KCCIDC('XYLOLIG')
      NTAR = KCCIDC('TAR')
      NMANO = KCCIDC('MANOLIG')
      NGALO = KCCIDC('GALAOLIG')
      NARAO = KCCIDC('ARABOLIG')
      NACET = KCCIDC('ACETATE')
      NACEO = KCCIDC('ACETOLIG')
      NXYLL = KCCIDC('XYLITOL')
C
C  *********************************************************************
C  *                                                                   *
C  *          SOLIDS DATABASE                                          *
C  *                                                                   *
C  *********************************************************************
C
      NCASO = KCCIDC('CASO4')
      NCAH2 = KCCIDC('CAH2O2')
      NASH = KCCIDC('ASH')
C
C  *********************************************************************
C  *                                                                   *
C  *          PURECOMPS DATABASE                                       *
C  *                                                                   *
C  *********************************************************************
C
      NETOH = KCCIDC('ETHANOL')
      NH2O = KCCIDC('H2O')
      NFURF = KCCIDC('FURFURAL')
      NHMF = KCCIDC('HMF')
      NH2SO = KCCIDC('H2SO4')
      NN2 = KCCIDC('N2')
      NCO2 = KCCIDC('CO2')
      NO2 = KCCIDC('O2')
      NCH4 = KCCIDC('CH4')
      NNO = KCCIDC('NO')
      NNO2 = KCCIDC('NO2')
      NNH3 = KCCIDC('NH3')
      NLACI = KCCIDC('LACID')
      NAACI = KCCIDC('AACID')
      NNH4O = KCCIDC('NH4OH')
```

```
      NNH4S = KCCIDC('NH4SO4')
      NNH4A = KCCIDC('NH4ACET')
      NGLYC = KCCIDC('GLYCEROL')
      NSUCC = KCCIDC('SUCCACID')
      NDENA = KCCIDC('DENAT')
      NOIL = KCCIDC('OIL')
      NCSL = KCCIDC('CSL')
      NCNUT = KCCIDC('CNUTR')
      NWNUT = KCCIDC('WNUTR')
      NSO2 = KCCIDC('SO2')
      NH2S = KCCIDC('H2S')
C
C   *********************************************************************
C   *                                                                   *
C   *         DEFINE THE OFFSETS FOR THE SUBSTREAMS                     *
C   *                                                                   *
C   *********************************************************************
C
C     S1 IS MIXED AND S2 IS CISOLID.
C
      S1=IDXSUB(1) - 1
      S2=IDXSUB(2) - 1
C
C   *********************************************************************
C   *                                                                   *
C   *        FIND THE MOLECULAR WEIGHT FOR COMPONENTS                   *
C   *        IN THE MIXED SS, CELL MASS AND (NH4)2SO4                   *
C   *********************************************************************
C
      LMW = IFCMNC ('MW')
      CMW = B(LMW + NBIOM)
      GMW = B(LMW + NGLUC)
      XYMW = B(LMW + NXYLO)
      UMW = B(LMW + NUNKN)
      SMW = B(LMW + NSOLS)
      AMW = B(LMW + NARAB)
      GAMW = B(LMW + NGALA)
      WAMW = B(LMW + NMANS)
      GOMW = B(LMW + NGLUO)
      CBMW = B(LMW + NCELB)
      XGMW = B(LMW + NXYLG)
      WOMW = B(LMW + NMANO)
      GLMW = B(LMW + NGALO)
      AOMW = B(LMW + NARAO)
      AEMW = B(LMW + NACEO)
      XLMW = B(LMW + NXYLL)
      EMW = B(LMW + NETOH)
      FMW = B(LMW + NFURF)
      HMW = B(LMW + NHMF)
      C4MW = B(LMW + NCH4)
      ALMW = B(LMW + NLACI)
      AAMW = B(LMW + NAACI)
      GYMW = B(LMW + NGLYC)
      SUMW = B(LMW + NSUCC)
      DMW = B(LMW + NDENA)
      WLMW = B(LMW + NOIL)
      WMW = B(LMW + NH2O)
      SAMW = B(LMW + NH2SO)
      W1MW = B(LMW + NN2)
      CO2MW = B(LMW + NCO2)
```

```
      W2MW = B(LMW + NO2)
      W3MW = B(LMW + NNO)
      W4MW = B(LMW + NNO2)
      AMMW = B(LMW + NNH3)
      CSMW = B(LMW + NCSL)
      CNMW = B(LMW + NCNUT)
      WNMW = B(LMW + NWNUT)
      WSOMW =B(LMW + NSO2)
      HSMW = B(LMW + NH2S)
      ASMW = B(LMW + NNH4S)
      AMAMW = B(LMW + NNH4A)
C
C  *********************************************************************
C  *                                                                   *
C  *       COPY INLET STREAM TO OUTLET STREAM                          *
C  *                                                                   *
C  *********************************************************************
C
C
C Copy Each Component, NCC - Number Conventional Components
C NCC+1 Total Flow
C S1 is MIXED substream, S2 is CISOLID
C
      DO 100 K = 1, NCC+1
         SOUT1(S1+K) = SIN1(S1+K)
         SOUT1(S2+K) = SIN1(S2+K)
         WRITE(NHSTRY,*)'K (Component No.) = ',K
         WRITE(NHSTRY,*)'SOUT1(S1) MIXED (kmol/s) = ',SOUT1(S1+K)
         WRITE(NHSTRY,*)'SOUT1(S2) CISOLID (kmol/s) = ',SOUT1(S2+K)
  100 CONTINUE
C
C Copy Stream Properties
C NCC+2 Temperature (K)
C NCC+3 Pressure (Pa)
C NCC+4 Enthalpy (J/Kg)
C NCC+5 Molar Vapor Fraction
C NCC+6 Molar Liquid Fraction
C NCC+7 Entropy (J/Kg K)
C NCC+8 Density (Kg/m^3)
C NCC+9 Molecular Weight
C
      DO 200 K=NCC+2, NCC+9
         SOUT1(S1+K) = SIN1(S1+K)
         SOUT1(S2+K) = SIN1(S2+K)
         WRITE(NHSTRY,*)'S1M,SO1M= ',SIN1(S1+K),SOUT1(S1+K)
         WRITE(NHSTRY,*)'SIC,SO1C= ',SIN1(S2+K),SOUT1(S2+K)
  200 CONTINUE
C
C
C  *********************************************************************
C  *                                                                   *
C  *       COPY ALL OF THE SOLUBLE NON-CARBON-CONTAINING COMPOUNDS     *
C  *       TO THE OUTLET STREAM.                                       *
C  *********************************************************************
C
C     THESE COMPONENTS WILL NOT BE CONVERTED.
C
       SOUT1(S1+NH2O)  = SIN1(S1+NH2O)
       SOUT1(S1+NH2SO) = SIN1(S1+NH2SO)
       SOUT1(S1+NN2)   = SIN1(S1+NN2)
```

```
      SOUT1(S1+NCO2)  = SIN1(S1+NCO2)
      SOUT1(S1+NO2)   = SIN1(S1+NO2)
      SOUT1(S1+NNO)   = SIN1(S1+NNO)
      SOUT1(S1+NNO2)  = SIN1(S1+NNO2)
      SOUT1(S1+NNH3)  = SIN1(S1+NNH3)
      SOUT1(S1+NCSL)  = SIN1(S1+NCSL)
      SOUT1(S1+NCNUT) = SIN1(S1+NCNUT)
      SOUT1(S1+NWNUT) = SIN1(S1+NWNUT)
      SOUT1(S1+NSO2)  = SIN1(S1+NSO2)
      SOUT1(S1+NH2S)  = SIN1(S1+NH2S)
C
C
C  *******************************************************************
C  *                                                                 *
C  *       SET THE METHANE YIELD                                     *
C  *                                                                 *
C  *******************************************************************
C
      CH4MAX = 350.
C CH4MAX IS THE MAXIMUM YIELD OF METHANE (L CH4/KG COD CONVERTED)
C AND WAS PROVIDED BY J. RUOCCO
C
      Write(NHSTRY,101)Real(1),Real(2),Real(3),Real(4),Real(5)
101   Format(' WWT Input Parameters',/,
     1       ' COD Converted in Anerobic:      ',g12.5,/,
     2       ' Methane Yield, Kg CH4/Kg COD:   ',g12.5,/,
     3       ' Cell Yield, Kg Cellmass/Kg COD: ',g12.5,/,
     4       ' Final Concentration of CH4:     ',g12.5,/,
     5       ' Frac of soluble SO4 converted:  ',g12.5)
      CODCON = REAL(1)
      CELLY = REAL(3)
      CODREM = 1.0-CODCON-CELLY
      CH4YLD = REAL(2)
C
C CODCON IS THE COD CONVERTED IN ANAEROBIC DIGESTION
C CELLY IS THE CELL YIELD KG CELL MASS/KG COD CONVERTED
C CODREM IS THE COD REMAINING AFTER ANAEROBIC DIGESTION
C CH4YLD IS THE METHANE YIELD KG CH4/KG COD CONVERTED
C
C  *******************************************************************
C  *                                                                 *
C  *       MODIFY THE METHANE YIELD BASED ON TEMP                    *
C  *                                                                 *
C  *******************************************************************
C
C THE FOLLOWING METHANE YIELD RELATIONSHIP BASED ON THE COD
C CONVERTED WAS OBTAINED FROM J. RUOCCO.
C
      WRITE(NHSTRY,*)'CODTOT,BODTOT= ',CODTOT, BODTOT
      IF (CODCON .GE. 0.9) THEN
         CODCON = 0.9
         CH4OUT = CODTOT*CH4MAX*CH4YLD*CODCON
      ELSE IF (CODCON .GT. 0.6) THEN
         CH4OUT = CODTOT*CH4MAX*CH4YLD*(1.0 + (CODCON - 0.9)*2.0)
      ELSE
         CH4OUT = CODTOT*CH4MAX*CH4YLD*(0.4 + (CODCON - 0.6)*5.0)
      END IF
C
C  *******************************************************************
C  *                                                                 *
```

```
C  *       CALCULATE METHANE PRODUCED                                     *
C  *                                                                      *
C  ************************************************************************
C
C     CONVERT L OF METHANE TO KG-MOL (SI UNITS)
      RHO = 1.0/(82.05*298.16)
C  RHO IS THE DENSITY OF CH4 AT 1 ATM AND 25C (298 K)
C  AND HAS UNITS OF KG MOL/L
C  8.314 IS THE UNIVERSAL GAS CONSTANT (ATM-L/KG-MOL K)
      CH4PRO = CH4OUT*RHO/3600.
C 3600 SEC/HR
      CH4MAS = CH4PRO*C4MW
C CH4MAS IS THE MASS FLOWRATE (KG/S) OF METHANE FROM THE SYSTEM
C      WRITE(NHSTRY,*)'CH4PRO= ',CH4PRO
C CH4PRO IS THE AMOUNT OF METHANE PRODUCED KG-MOL/S
C
      SOUT1(S1+NCH4) = (SIN1(S1+NCH4))*CODREM + CH4PRO
C
C  ************************************************************************
C  *                                                                      *
C  *       CALCULATE CELL MASS PRODUCED                                    *
C  *                                                                      *
C  ************************************************************************
C
C CELLY IS THE CELL YIELD IN KG/KG COD CONVERTED
      CELLM = CELLY*CODTOT*CH4YLD*CODCON
C
C CONVERT CELLS (KG/HR) TO KG-MOL/S
C
      CELLS = CELLM/(3600*CMW)
      SOUT1(S2+NBIOM) = SIN1(S2+NBIOM) + CELLS
C
C Adding Cell mass to the CISOLID substream and removing Mass from MIXED
C
      SOUT1(S2+NCC+1) = SOUT1(S2+NCC+1) + SOUT1(S2+NBIOM)
      SOUT1(S1+NCC+1) = SOUT1(S1+NCC+1) - SOUT1(S2+NBIOM)
C
C  ************************************************************************
C  *                                                                      *
C  *       CALCULATE SOLUBLE C-CONTAINING COMPOUNDS LEFT                  *
C  *                                                                      *
C  ************************************************************************
C
      SOUT1(S1+NGLUC) = CODREM*SIN1(S1+NGLUC)
      SOUT1(S1+NXYLO) = CODREM*SIN1(S1+NXYLO)
      SOUT1(S1+NUNKN) = CODREM*SIN1(S1+NUNKN)
      SOUT1(S1+NSOLS) = CODREM*SIN1(S1+NSOLS)
      SOUT1(S1+NARAB) = CODREM*SIN1(S1+NARAB)
      SOUT1(S1+NGALA) = CODREM*SIN1(S1+NGALA)
      SOUT1(S1+NMANS) = CODREM*SIN1(S1+NMANS)
      SOUT1(S1+NGLUO) = CODREM*SIN1(S1+NGLUO)
      SOUT1(S1+NCELB) = CODREM*SIN1(S1+NCELB)
      SOUT1(S1+NXYLG) = CODREM*SIN1(S1+NXYLG)
      SOUT1(S1+NMANO) = CODREM*SIN1(S1+NMANO)
      SOUT1(S1+NGALO) = CODREM*SIN1(S1+NGALO)
      SOUT1(S1+NARAO) = CODREM*SIN1(S1+NARAO)
      SOUT1(S1+NACEO) = CODREM*SIN1(S1+NACEO)
      SOUT1(S1+NXYLL) = CODREM*SIN1(S1+NXYLL)
      SOUT1(S1+NETOH) = CODREM*SIN1(S1+NETOH)
      SOUT1(S1+NFURF) = CODREM*SIN1(S1+NFURF)
```

```
      SOUT1(S1+NHMF)  = CODREM*SIN1(S1+NHMF)
      SOUT1(S1+NLACI) = CODREM*SIN1(S1+NLACI)
      SOUT1(S1+NAACI) = CODREM*SIN1(S1+NAACI)
      SOUT1(S1+NGLYC) = CODREM*SIN1(S1+NGLYC)
      SOUT1(S1+NSUCC) = CODREM*SIN1(S1+NSUCC)
      SOUT1(S1+NDENA) = CODREM*SIN1(S1+NDENA)
      SOUT1(S1+NOIL)  = CODREM*SIN1(S1+NOIL)
      SOUT1(S2+NNH4A)  = CODREM*SIN1(S2+NNH4A)
C
C Subtracting converted NH4ACET (Not Remaining) from CISOLID substream and
C adding Mass to MIXED
C
      SOUT1(S2+NCC+1) = SOUT1(S2+NCC+1) - (SIN1(S2+NNH4A)
     1                - SOUT1(S2+NNH4A))
      SOUT1(S1+NCC+1) = SOUT1(S1+NCC+1) + (SIN1(S2+NNH4A)
     1                - SOUT1(S2+NNH4A))
CC
C  *****************************************************************
C  *                                                               *
C  *       CALCULATE MASS OF REACTABLE SUBSTANCES INTO DIGESTOR    *
C  *                                                               *
C  *****************************************************************
C
      REACIN =  SIN1(S1+NGLUC)*GMW +  SIN1(S1+NXYLO)*XYMW +
     2          SIN1(S1+NUNKN)*UMW +  SIN1(S1+NSOLS)*SMW +
     3          SIN1(S1+NARAB)*AMW +  SIN1(S1+NGALA)*GAMW +
     4          SIN1(S1+NMANS)*WAMW +  SIN1(S1+NGLUO)*GOMW +
     5          SIN1(S1+NCELB)*CBMW +  SIN1(S1+NXYLG)*XGMW +
     6          SIN1(S1+NMANO)*WOMW +  SIN1(S1+NGALO)*GLMW +
     7          SIN1(S1+NARAO)*AOMW +  SIN1(S1+NACEO)*AEMW +
     8          SIN1(S1+NXYLL)*XLMW +  SIN1(S1+NETOH)*EMW +
     9          SIN1(S1+NFURF)*FMW  +  SIN1(S1+NHMF)*HMW  +
     *          SIN1(S1+NCH4)*C4MW  +  SIN1(S1+NLACI)*ALMW +
     1          SIN1(S1+NAACI)*AAMW +  SIN1(S1+NGLYC)*GYMW +
     2          SIN1(S1+NSUCC)*SUMW +  SIN1(S1+NDENA)*DMW +
     3          SIN1(S1+NOIL)*WLMW   + SIN1(S2+NNH4A)*AMAMW

C
C  CALCULATE THE MASS THAT REACTED
C
      REACTD = (1.-CODREM)*REACIN
C
C  *****************************************************************
C  *                                                               *
C  *       CALCULATE CO2 PRODUCTION                                *
C  *                                                               *
C  *****************************************************************
C
C  CALCULATE THE AMOUNT AVAILABLE FOR CO2 PRODUCTION
C
      CO2AVL = REACTD - (CELLM/3600.) -  CH4MAS
C
      WRITE(NHSTRY,*)'CO2AVL= ',CO2AVL
C CALCULATE THE FINAL FLOWRATE OF CO2 OUT
C
      CO2OUT = CO2AVL/CO2MW
      WRITE(NHSTRY,*)'CO2OUT= ',CO2OUT
C DETERMINE THE MOLE FRACTION OF CO2 POTENTIALLY FORMED
      CO2FRC = CO2OUT/(CO2OUT + CH4PRO)
C     THE FINAL CONCENTRATION OF  CH4 MAY BE SET
```

```
      CH4FIN = REAL(4)
      CO2FIN = CH4PRO/CH4FIN - CH4PRO
      WRITE(NHSTRY,*)'CO2FIN= ',CO2FIN
C CHECK TO SEE IF THE CO2 CALCULATED BY SETTING THE VOLUMETRIC
C OUTLET IS GREATER THAN THE POTENTIAL FORMED.  IF SO, THEN SET
C THE CO2 OUT EQUAL TO THE MAXIMUM POTENTIAL.  IF NOT, SET THE
C CO2 FORMED EQUAL TO THE VOLUMETRIC SPECIFICATION AND MAKE
C WATER WITH THE REMAINING.
      IF (CO2FIN .GT. CO2OUT) THEN
         SOUT1(S1+NCO2) = CO2OUT + SIN1(S1+NCO2)
      ELSE
         SOUT1(S1+NCO2) = CO2FIN + SIN1(S1+NCO2)
         SOUT1(S1+NH2O) = (CO2OUT-CO2FIN)*(CO2MW/WMW)+SOUT1(S1+NH2O)
      END IF
C
C   AS A CHECK, CALCULATE THE MOLE FRACTION CO2 VS CH4
C   AND WRITE OUT THE RESULTS.
C
      CO2FRC = SOUT1(S1+NCO2)/(SOUT1(S1+NCO2) + SOUT1(S1+NCH4))
      CH4FRC = SOUT1(S1+NCH4)/(SOUT1(S1+NCO2) + SOUT1(S1+NCH4))
C
      WRITE(NHSTRY,*)'CO2FRC,CH4FRC= ',CO2FRC,CH4FRC
C
C
C  *********************************************************************
C  *                                                                   *
C  *       CALCULATE H2S PRODUCTION                                    *
C  *                                                                   *
C  *********************************************************************
C
C  ASSUME H2S WILL BE FORMED FROM ALL SOLUBLE SO4-CONTAINING COMPOUNDS
C
       SACON = 0.347
C SACON IS THE SULFURIC ACID CONVERSION TO H2S (LB H2S/LB H2SO4)
      ASCON = 0.273
C ASCON IS THE AMMONIUM SULFATE CONVERSION TO H2S (LB H2S/LB (NH4)2SO4)
C
       CEFF = REAL(5)
C      CEFF = FRACTION OF SOLUBLE SO4-CONTAINING COMPOUNDS CONVERTED
C
      H2SFRM = SACON*SIN1(S1+NH2SO)*SAMW*CEFF +
     1         ASCON*SIN1(S2+NNH4S)*ASMW*CEFF
C H2SFRM IS THE AMOUNT OF H2S FORMED (KG/S)
C
      H2SMOL = H2SFRM/HSMW
C H2SMOL IS THE H2S FORMED ON A MOLE BASIS (KG-MOL/S)
C
      WRITE(NHSTRY,*)'H2SFRM,H2SMOL= ',H2SFRM,H2SMOL
C ASSUME WHAT IS NOT CONVERTED TO H2S GOES TO WATER
C
      WATFRM = (1-SACON)*SIN1(S1+NH2SO)*SAMW*CEFF +
     1         (1-ASCON)*SIN1(S2+NNH4S)*ASMW*CEFF
      WATMOL = WATFRM/WMW
      WRITE(NHSTRY,*)'WATFRM,WATMOL= ',WATFRM,WATMOL
C
      SOUT1(S1+NH2SO) = (1.0-CEFF)*SIN1(S1+NH2SO)
      SOUT1(S2+NNH4S) = (1.0-CEFF)*SIN1(S2+NNH4S)
C CALCULATE THE OUTLET FLOWRATES
      SOUT1(S1+NH2S) = SOUT1(S1+NH2S) + H2SMOL
      SOUT1(S1+NH2O) = SOUT1(S1+NH2O) + WATMOL
```

```
C
      RETURN
      END
```

Attachment 3
Wastewater Treatment Calculation Spreadsheets

Aerobic Digestion Energy Balance Calculations

Cell Mass MW	**23.238**	**% Conversion to Cell Mass**	**30.00%**
Cell Mass HHV	**9,843**	**% Total Conversion**	**90.00%**
		% Conversion to CO2/H2O	**60.00%**

Basis: **1 lb component -------> 1 lb cell mass**

Mixed SS Component	COD kg/kg	MW	Stoich. Factor MWComp/ MW Cells	HHV (Btu/lb)	HHV Product (Btu/lb)	HHV Decrease (Btu/lb)	
Glucose/Mannose/Galactose	1.07	180.16	7.7528	6,729	2952.9	3775.8	OK
Xylose/Arabinose	1.07	150.132	6.4606	6,739	2952.9	3786.31	OK
Xylitol	1.22	152.15	6.5475	7,458	2952.9	4504.7	OK
Soluble Solids	0.711	16.5844	0.7137	14,360	2952.9	11407.35	OK
Soluble Unknown	1.07	15.0134	0.6461	6,201	2952.9	3248.44	OK
C-6 Oligomers	1.07	162.115	6.9763	6,719	2952.9	3766.4	OK
C-5 Oligomers	1.07	132.0942	5.6844	6,729	2952.9	3775.9	OK
Cellobiose	1.07	342.2398	14.7276	8,306	2952.9	5352.6	OK
Furfural	1.67	96	4.1312	9,107	2952.9	6153.7	OK
HMF	1.52	126.1116	5.4270	10,296	2952.9	7343.1	OK
Acetic Acid	1.07	60	2.5820	6,463	2952.9	3510.2	OK
Lactic Acid	1.07	90	3.8730	6,470	2952.9	3516.7	OK
Succinic Acid	0.95	118	5.0779	5,483	2952.9	2530.5	OK
Glycerol	1.22	92	3.9590	7,720	2952.9	4767	OK
Oil	2.89	282	12.1353	17,045	2952.9	14091.7	OK
Ethanol	2.09	46	1.9795	12,762	2952.9	9809.1	OK

Anaerobic Digestion Yields

CH4 Yield	**350**	**l/kg COD converted**
	0.2214793	**kg CH4/kgCOD converted at 35 C**
Cell Yield	**0.03**	**kg/kg COD converted**

Compound	COD kg/kg	CH4 kg	Cell Mass kg	Potential CO2 kg	CH4 Wt Frac	CO2 Wt Frac	CH4 Moles	CO2 Moles	CH4 Molar Frac	CO2 Molar Frac
Glucose, Xylose, etc.	1.07	0.237	0.032	0.731	0.245	0.755	0.015	0.017	0.463	0.537
Furfural	1.67	0.370	0.050	0.580	0.389	0.611	0.023	0.014	0.625	0.375
HMF	1.52	0.337	0.046	0.618	0.353	0.647	0.021	0.015	0.589	0.411
Ethanol	2.09	0.463	0.063	0.474	0.494	0.506	0.029	0.012	0.716	0.284
Lactic Acid	1.07	0.237	0.032	0.731	0.245	0.755	0.015	0.017	0.463	0.537
Acetic Acid	1.07	0.237	0.032	0.731	0.245	0.755	0.015	0.017	0.463	0.537
Glycerol	1.22	0.270	0.037	0.693	0.280	0.720	0.017	0.016	0.508	0.492
Succinic Acid	0.95	0.210	0.029	0.761	0.217	0.783	0.013	0.018	0.425	0.575
Xylitol	1.22	0.270	0.037	0.693	0.280	0.720	0.017	0.016	0.508	0.492

Attachment 4

COD Data and Projected Calculations

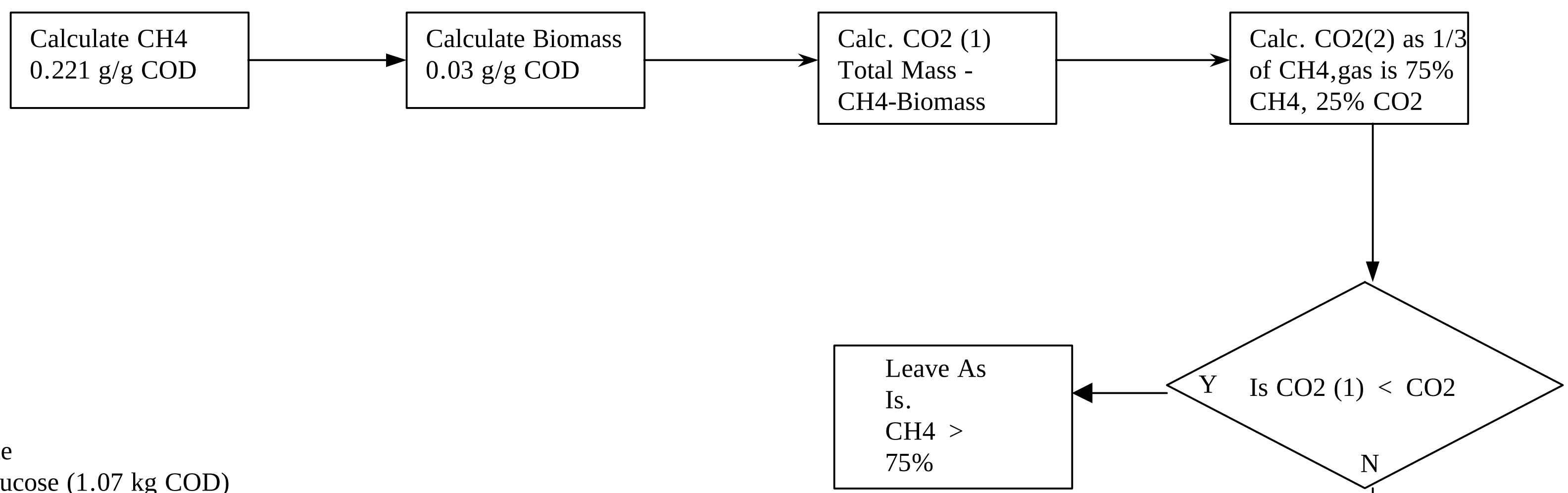
Projected COD Calculation
Comparison with Actual Data

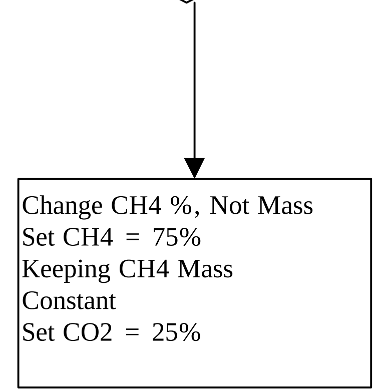
Compound	Concentration (mg/L)	COD Factor kg O2/kg comp.	Estimated COD kg O2
Cellobiose (incl. w/glucose)	0	1.07	0
Glucose	6,140	1.07	6,570
Galactose	2,170	1.07	2,322
Mannose	4,420	1.07	4,729
Xylose	2,840	1.07	3,039
Arabinose	700	1.07	749
Ethanol	0	2.09	0
Cell Mass*	1,800	0	0
Glycerol	1,020	1.22	1,244
Xylitol	950	1.22	1,159
Acetic Acid	2,980	1.07	3,189
Lactic Acid	3,330	1.07	3,563
Succinic Acid	1,930	0.95	1,834
		Total	**28,398**
		Avg. COD measured	**27,199**

* Cell mass is insoluble and so it has an assumed COD of 0

Attachment 5

Calculation Flow Diagram





Example
1 kg Glucose (1.07 kg COD)
90% Conversion of COD

CH_4 = (1.07 * 0.221 * 0.9) = 0.213 kg
Biomass = (1.07 * 0.03 * 0.9) = 0.0321 kg

A) Based on mass balance
1-0.213 - 0.0321 = 0.7549 kg CO_2
0.213/16 = 0.013 moles CH_4
0.7549/44 = 0.017 moles CO_2
0.013/0.030 = 43 % CH_4
0.017/0.030 = 57% CO_2 (A)

B) Set CH_4 = 75%
CO_2(B) = 0.013 moles CH_4/0.75 - 0.013 = 0.0043 moles
CO_2(A) < CO_2(B) N, Change CO_2

New CO_2 = 0.75 * 0.013 = 0.033 moles of CO_2
0.098 * 44 = 0.143 kg CO_2
Remainder H_2O, 1 - 0.143 - 0.7549 = 0.1021 kg H_2O

Example
1 kg Corn Oil (2.89 kg COD)
90% Conversion of COD

CH_4 = (2.89 * 0.221 * 0.9) = 0.575 kg
Biomass = (2.89 * 0.03 * 0.9) = 0.078 kg

A) Based on mass balance
1 - 0.575 - 0.078 = 0.347 kg CO_2 (A)
0.575/16 = 0.036 moles CH_4
0.347/44 = 0.008 moles
0.036/0.044 = 82% CH_4
0.008/0/044 = 18% CO_2 (A)

B) Set CH_4 = 75%
CO_2 (B) = 0.036 Moles CH_4/.75 - 0.036 = 0.012 moles

Appendix H

Evaporator Syrup Disposition

EVALUATION OF ALTERNATE EVAPORATOR SYRUP DISPOSITIONS

8/10/98 Rev 2

BASIS

From ASPEN model, 7/22/98, R9805M, stream 531:

Total Flow	81023 kg/hr, 356 gpm (was 260 gpm prior to Delta T input)
Insolubles	1.8%
Solubles	5.9%
Temp.	62 ^{O}C
Pressure	0.21 atmos. ??

Soluble Composition:

Ethanol		1 kg/hr
Water	69910	
Xylose	393	
Arabinose		315
Other sugars	1625	
Cellobiose		213
Glucose Oligomers	1025	
Xylose Oligomers	556	
Acetic Acid	1456	
Sulfuric Acid	246	
Furfural		27
HMF		244

Insolubles Composition:

Cellulose		54 kg/hr
Xylan	12	
Other sugar polymers	2	
Biomass		397
Zymo	397	
Lignin	346	

Assumptions

- Note that all of the following costs are for incremental changes from a base case and are not the total installed cost of the facilities. In the base case there is no defined destination for the syrup and there are no capital or operating expenses for the handling and disposal of the syrup.

- In calculating the capitalized costs, operating costs are taken to equal capital costs in three to five years. For example, 3 to 5 years of fuel costs of $1000/yr are equivalent to $3000 to $5000 in capital cost on the first day.

- Delta-T has evolved a design of the evaporator and distillation systems to include a 3-effect evaporator that , presumably, uses the available heat from the distillation system. The reason that the syrup stream (Stream 531) is now only 7.7% solids concentration is that this is the maximum concentration available from "free" heat with a 3-effect system.

- Flow rate for Stream 531 is therefore larger due to the lower concentration. The stream is now about 356 GPM rather than 260 GPM.

- Corn-to-ethanol designs that maximize syrup concentration to about 75% solids are not "achievable" using the Delta-T design.

- There is no proposed use of the syrup as a product stream. Merrick proposes design alternatives of <u>syrup use in the existing lignin fired boiler</u> for:

  Case 1 fuel sprayed on lignin boiler fuel - as is
  Case 2 additional evaporation (separate step or 4th effect) to fuel value = zero
  Case 3 use of "free" low level heat with additional evaporation to fuel = zero

  or <u>treatment as wastewater</u>:
  Case 4 Treatment of the syrup stream in the waste water unit
  A. Syrup has separate waste water unit from other plant waste water streams due to its high (75,000 mg/L) COD
  B. Syrup and other waste waters have separate anaerobic treaters but share the aerobic treating unit
  C. Syrup and other waste waters are blended upstream of waste water treating.
  (Please see attached block schematic.)

  Case 5 Deletion of the 2nd and 3rd effects of the evaporator (downstream of the centrifuge) with the more dilute "syrup" sent to anaerobic/aerobic treatment.

  Case 6 All three evaporator effects are deleted. Distillation bottoms is centrifuged (possibly other separation devices ?) to remove lignin as a cake having the same water content as the current design. Seventy five percent of the liquor stream goes to anaerobic water treat and the remaining 25% is recycled (possibly after dilution with treated water).

- The average heat of combustion of the solids in the syrup was taken to be 8000 BTU/lb. Water was vaporized at atmospheric pressure in calculating net heating value of the stream.

- The following utility costs are used in the evaluation:
  - Fuel gas = $2.00 per mmBTU
  - Fresh water = $2.00 per 1000 gallons
  - Electric power = $0.042 per KWH
  - Sludge disposal = $ 0.015 per pound

CASE 1

Leave the evaporator as it is currently designed in the model. Spray the syrup on the lignin and burn it in the boiler. Since syrup is largely water, additional water will need to be made up compared to cases where this water is reclaimed and recycled.

1. Incremental Capital Cost: $200k spraying equipment.

2. Incremental Fuel Cost: $88,440 / yr

3. Incremental Water Costs: $342,150 / yr

4. Incremental Power Costs: $0

5. Incremental Sludge Costs $0

CASE 2

Add additional evaporating capacity either as a fourth effect to the current evaporator (greater vacuum) or as a stand alone single effect evaporator. Assume each of these options is roughly equivalent in capital cost. Increase the concentration of the solids in the syrup until the heat of combustion of the solids is exactly equal to the heat required to evaporate all of the remaining water in the syrup stream. More net heat is available in the boiler (more steam produced) but this is offset by increased heat use in the evaporator(s). Assume that Delta T used all of the available waste heat in the evaporator and "new" heat is at the cost of fuel gas.

1. Incremental Capital Cost : $1,400k + 200k = $1,600k

2. Incremental Fuel Cost : $143,425

3. Incremental Water Costs : $324,180

4. Incremental Power Costs $0

5. Incremental Sludge Costs $0

CASE 3

Assume that there is additional low temperature level heat available from somewhere in the process. Appendix A of the report indicates that this likely. For example, distillation reflux condensers are large heat loads containing heat which might be useful here. Add evaporation capital cost and assume that syrup will be concentrated until the heat of combustion of the syrup exactly matches the heat to vaporize the water in the syrup.

1. Incremental Capital Cost : $1,400 + $200 = $1,600

2. Incremental Fuel Cost : $0

3. Incremental Water Costs : $324,180

4. Incremental Power Costs $0

5. Incremental Sludge Costs $0

CASE 4

With evaporation remaining as it is currently designed route the syrup to water treating in one of the ways described below. (See attached block schematic)

Subcase A In this case syrup containing 75,000 mg/L COD is processed in a separate train of anaerobic and aerobic equipment. The remainder of the waste water (mixed waste) which contains only 16,000 mg/L COD has its own train of equipment.

1. Incremental Capital Cost: $4,238K

2. Incremental Fuel Cost: ($272,500)

3. Incremental Water Costs: $0

4. Incremental Poer Costs $460,020

5. Incremental Sludge Costs $72,436

Subcase B In this case the syrup and the mixed waste have separate anaerobic treating equipment but share the aerobic treating.

1. Incremental Capital Cost: $4,159K

2. Incremental Fuel Cost: ($272,500)

3. Incremental Water Costs: $0

4. Incremental Power Cost: $460,500

5. Incremental Sludge Cost: $72,436

Subcase C In this case syrup and mixed waste are blended upstream of waste water treatment and therefore share all treating equipment.

1. Incremental Capital Cost: $3,390K

2. Incremental Fuel Cost: ($272,500)

3. Incremental Water Costs: $0

4. Incremental Power Cost: $460,500

5. Incremental Sludge Cost: $72,436

In addition to capital cost the following operating cost factors must be considered in making the water treating process evaluations.

- The CO_2/Methane gas produced in anaerobic treatment has a positive fuel value equal to $2.00 per mmBTU.
- The aerobic blower/compressor electric power consumption should be valued at $0.042 per KWH.
- Treated water is recycled to the process and therefore backs out fresh water. The recycled water should be valued at $2.00 per 1000 gallons.
- Aerobic sludge has a cost for disposal of 1.5 cents per pound.

CASE 5

This case considers deleting the 2nd and 3rd effects of the evaporator and processing the dilute waste water directly in anaerobic and aerobic treatment. The first effect was not deleted because the size of the expensive centrifuge(s) would be drastically increased. Feed to water treating is increased by 600 gpm over Case 1 because water which was backset from the 2nd and 3rd effects must now be processed in water treating.

1. Incremental Capital Cost: $1,942K

2. Incremental Fuel Cost: ($272,500)

3. Incremental Water Costs: $0

4. Incremental Power Cost: $652,460

5. Incremental Sludge Cost: $96,576

CASE 6

This case considers complete elimination of the evaporator. Distillation bottoms would be processed in centrifuges or similar separation devices. Cake, having the same water content as the current design would be the lignin stream to the boiler burner. The centrifuge liquor would be split with 25% recycle to the process with treated water and 75% sent directly to anaerobic treating.

1. Incremental Capital Cost: $27,551K

2. Incremental Fuel Cost: ($272,500)

3. Incremental Water Costs: $0

4. Incremental Power Cost: $1,545K

5. Incremental Sludge Cost: $368,841

OVERALL COMPARISON:

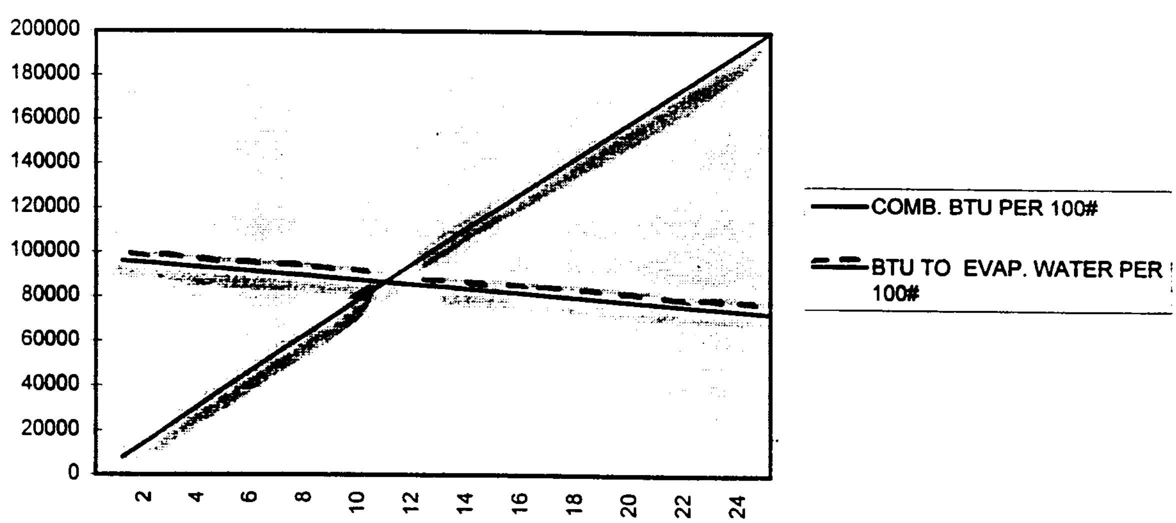
	Capitalized Capital $	Operating Costs: Fuel $	Water $	Sludge	Electric Power $	Total $ * 3 Year	5 Year
Case 1	$200K	$88,440	$342,150	$0	$0	$1,492K	$2,353K
Case 2	$1,600K	$143,425	$324,180	$0	$0	$3,003K	$3,938K
Case 3	$1,600K	$0	$324,180	$0	$0	$2,573K	$3,221K
Case 4							
A	$4,238K	($272,500)	$0	$72,436	$460,020	$5,017K	$5,538K
B	$4,159K	($272,500)	$0	$72,436	$460,500	$4,940K	$5,460K
C	$3,390K	($272,500)	$0	$72,436	$460,500	$4,171K	$4,692K
Case 5	$1,942K	($272,500)	$0	$96,576	$652,460	$3,312K	$4,225K
Case 6	$27,551K	($272,500)	$0	$368,841	$1,545K	$32,475K	$35,758K

* For example, the expenditure of $1000 per year in operating cost for 3 years or the expenditure of $3000 additional capital in the first year are equivalent.

CONCLUSION:

From the comparison made above, Case 1 is the most economical choice for evaporator syrup treatment. In Case 1 the fuel is sprayed onto the lignin boiler fuel. It is the least costly in both the three and five year capitalized total. Case 1 would be the best and most cost-effective process to use in the treatment of the evaporator syrup.

NREL SOFTWOOD	EVAPORATOR SYRUP			7/23/98
		BTU TO	NET HEAT	
PERCENT	COMB. BTU	EVAP. WATER	OF COMB.	
SOLIDS [1]	PER 100#	PER 100#	BTU/100lbs [2]	
1	8000	96060	-89271.7	
2	16000	95089	-81513.4	
3	24000	94119	-73755.1	
4	32000	93149	-65996.8	
5	40000	92179	-58238.5	
6	48000	91208	-50480.2	
7	56000	90238	-42721.9	
8	64000	89268	-34963.6	
9	72000	88297	-27205.3	
10	80000	87327	-19447	
11	88000	86357	-11688.7	
12	96000	85386	-3930.4	← BREAK EVEN
13	104000	84416	3827.9	
14	112000	83446	11586.2	
15	120000	82476	19344.5	
16	128000	81505	27102.8	
17	136000	80535	34861.1	
18	144000	79565	42619.4	
19	152000	78594	50377.7	
20	160000	77624	58136	
21	168000	76654	65894.3	
22	176000	75683	73652.6	
23	184000	74713	81410.9	
24	192000	73743	89169.2	
25	200000	72773	96927.5	



1. Both soluble and insoluble.

2. Less heat lost in flue gas @ 350 ^{o}F.

Ethanol Production Process Engineering Analysis

NREL Year 2000 Case Co-Current Pretreatment & Enzymatic Hydrolysis

Syrup to Burner

All Values in 1995$

Ethanol Production Cost **$1.37**

Ethanol Production (MM Gal. / Year)	54.5
Ethanol Yield (Gal / Dry Ton Feedstock)	74
Feedstock Cost $/Dry Ton	15

Capital Costs	
Feed Handling	$4,900,000
Pretreatment/Detox	$25,300,000
SSCF	$14,300,000
Cellulase	$11,600,000
Distillation	$12,200,000
WWT	$12,300,000
Storage	$1,800,000
Boiler/Turbogen	$31,400,000
Utilities	$8,500,000
Total Equipment Cost	$122,300,000
Added Costs	$89,800,000
(% of TEC)	42%
Total Project Investment	$212,100,000

Operating Costs (cents/gal ethanol)	
Feedstock	21.3
CSL	5.0
Denaturant	3.9
Other Raw Materials	14.7
Waste Disposal	1.3
Electricity	-3.3
Fixed Costs	21.3
Capital Recovery	72.4

Operating Costs ($/yr)	
Feedstock	$11,600,000
CSL	$2,800,000
Denaturant	$2,100,000
Other Raw Matl. Costs	$8,000,000
Waste Disposal	$700,000
Electricity Credit	-$1,800,000
Fixed Costs	$11,600,000
Capital Recovery	$39,500,000

Cap. Recovery Factor 0.186

Theoretical Yields	Ethanol MM Gal/year
Cellulose	59.3
Xylan	27.1
Arabinan	1.1
Mannan	5.5
Galactan	0.3
Total Maximum (MM Gal/yr)	93.3
Maximum Yield (Gal/ton)	127.2
Current Yield (Actual/Theor)	58%

Ethanol Production Process Engineering Analysis

NREL Year 2000 Case Co-Current Pretreatment & Enzymatic Hydrolysis

Syrup to WWT

All Values in 1995$

Ethanol Production Cost **$1.43**

Ethanol Production (MM Gal. / Year)	54.5
Ethanol Yield (Gal / Dry Ton Feedstock)	74
Feedstock Cost $/Dry Ton	15

Capital Costs	
Feed Handling	$4,900,000
Pretreatment/Detox	$25,300,000
SSCF	$14,300,000
Cellulase	$11,600,000
Distillation	$12,200,000
WWT	$17,300,000
Storage	$1,800,000
Boiler/Turbogen	$29,400,000
Utilities	$8,700,000
Total Equipment Cost	$125,600,000
Added Costs	$91,900,000
(% of TEC)	42%
Total Project Investment	$217,500,000

Operating Costs (cents/gal ethanol)	
Feedstock	21.3
CSL	5.0
Denaturant	3.9
Other Raw Materials	15.7
Waste Disposal	1.4
Electricity	-0.1
Fixed Costs	21.7
Capital Recovery	74.1

Operating Costs ($/yr)	
Feedstock	$11,600,000
CSL	$2,800,000
Denaturant	$2,100,000
Other Raw Matl. Costs	$8,500,000
Waste Disposal	$800,000
Electricity Credit	-$100,000
Fixed Costs	$11,800,000
Capital Recovery	$40,400,000

Cap. Recovery Factor 0.186

Theoretical Yields	Ethanol MM Gal/year
Cellulose	59.3
Xylan	27.1
Arabinan	1.1
Mannan	5.5
Galactan	0.3
Total Maximum (MM Gal/yr)	93.3
Maximum Yield (Gal/ton)	127.2
Current Yield (Actual/Theor)	58%

Ethanol Production Process Engineering Analysis

NREL Year 2000 Case Co-Current Pretreatment & Enzymatic Hydrolysis

Syrup to Nowhere

All Values in 1995$

Ethanol Production Cost **$1.37**

Ethanol Production (MM Gal. / Year)	54.5
Ethanol Yield (Gal / Dry Ton Feedstock)	74
Feedstock Cost $/Dry Ton	15

Capital Costs	
Feed Handling	$4,900,000
Pretreatment/Detox	$25,300,000
SSCF	$14,300,000
Cellulase	$11,600,000
Distillation	$12,200,000
WWT	$12,300,000
Storage	$1,800,000
Boiler/Turbogen	$28,900,000
Utilities	$8,300,000
Total Equipment Cost	$119,700,000
Added Costs	$88,100,000
(% of TEC)	42%
Total Project Investment	$207,800,000

Operating Costs (cents/gal ethanol)	
Feedstock	21.3
CSL	5.0
Denaturant	3.9
Other Raw Materials	14.6
Waste Disposal	1.3
Electricity	-0.5
Fixed Costs	21.0
Capital Recovery	70.8

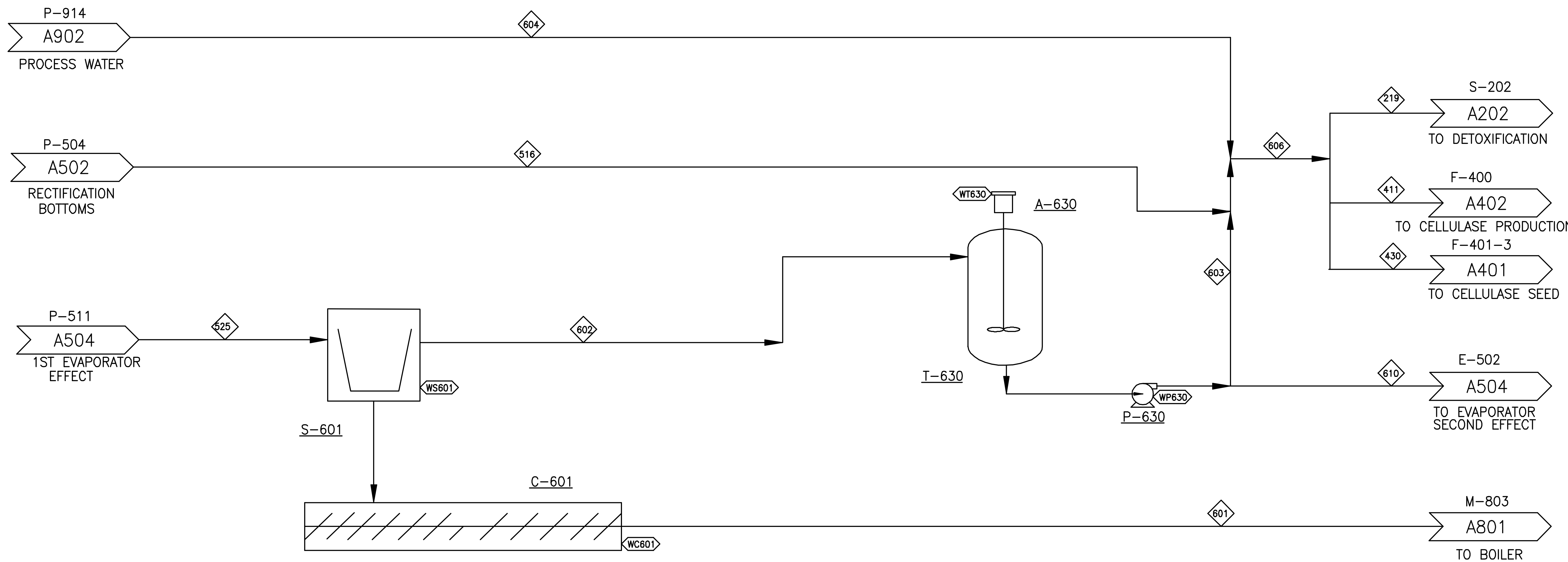
Operating Costs ($/yr)	
Feedstock	$11,600,000
CSL	$2,800,000
Denaturant	$2,100,000
Other Raw Matl. Costs	$8,000,000
Waste Disposal	$700,000
Electricity Credit	-$200,000
Fixed Costs	$11,400,000
Capital Recovery	$38,600,000

Cap. Recovery Factor 0.186

Theoretical Yields	Ethanol MM Gal/year
Cellulose	59.3
Xylan	27.1
Arabinan	1.1
Mannan	5.5
Galactan	0.3
Total Maximum (MM Gal/yr)	93.3
Maximum Yield (Gal/ton)	127.2
Current Yield (Actual/Theor)	58%

Appendix I

Process Flow Diagrams



COMPONENT	UNITS	219	411	430	516	525	601	602	603	604	606	610
Total Flow	kg/hr	132,211	22,766	2,146	30,943	278,666	98,808	179,858	44,965	81,215	157,123	134,894
Insoluble Solids	%	0.2%	0.2%	0.2%	0.0%	11.4%	30.5%	0.9%	0.9%	0.0%	0.2%	0.9%
Soluble Solids	%	1.1%	1.1%	1.1%	0.7%	3.8%	4.4%	3.5%	3.5%	0.0%	1.1%	3.5%
Temperature	C	47	47	47	121	86	40	40	40	20	47	40
Pressure	atm	1.00	1.00	1.00	2.06	0.59	3.20	3.20	3.20	1.00	1.00	3.20
Vapor Fraction		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethanol	kg/hr	19	3	0	16	42	11	30	8		23	23
Water	kg/hr	128,285	22,090	2,082	29,822	227,738	62,056	165,682	41,420	81,215	152,457	124,261
Glucose (SS)	kg/hr	0	0	0	0	219	219				0	
Xylose (SS)	kg/hr	110	19	2	0	721	196	524	131		131	393
Arabinose (SS)	kg/hr	87	15	1	0	570	155	415	104		104	311
Other Sugars (SS)	kg/hr	450	78	7	0	2,942	802	2,141	535		535	1,605
Cellobiose (SS)	kg/hr	59	10	1	0	383	104	279	70		70	209
Glucose Oligomers (SS)	kg/hr	464	80	8	0	3,030	826	2,204	551		551	1,653
Xylose Oligomers (SS)	kg/hr	154	27	3	0	1,009	275	734	183		183	550
Other Oligomers (SS)	kg/hr											
Corn Steep Liquor (SS)	kg/hr	191	33	3	227	1,720	1,720				227	
(NH4)2SO4 (SS)	kg/hr											
NH4Acetate (SS)	kg/hr											
Others (Soluble Solids)	kg/hr	3	1	0	0	29	14	14	4		4	11
Acetic Acid	kg/hr	453	78	7	122	2,293	625	1,668	417		539	1,251
Sulfuric Acid	kg/hr	45	8	1	0	295	80	214	54		54	161
Furfural	kg/hr	487	84	8	542	203	55	148	37		579	111
HM F	kg/hr	164	28	3	183	68	19	50	12		195	37
Carbon Dioxide	kg/hr	0	0	0	0						0	
M ethane	kg/hr											
Oxygen	kg/hr											
Nitrogen	kg/hr											
Ammonia	kg/hr	10	2	0	11	0	0	0	0		11	0
NH4OH	kg/hr											
Others	kg/hr	900	155	15	21	5,743	1,547	4,196	1,049		1,070	3,147
Cellulose (IS)	kg/hr	15	3	0		3,631	3,559	73	18		18	54
Xylan (IS)	kg/hr	3	1	0		794	778	16	4		4	12
Arabinan (IS)	kg/hr	0	0	0		33	32	1	0		0	0
Other Sugar Polymers (IS)	kg/hr	1	0	0		164	161	3	1		1	2
Cellulase (IS)	kg/hr	66	11	1		625	312	312	78		78	234
Biomass (IS)	kg/hr	26	4	0		245	123	123	31		31	92
Zymo (IS)	kg/hr	112	19	2		1,062	531	531	133		133	398
Lignin (IS)	kg/hr	97	17	2		23,068	22,607	461	115		115	346
Gypsum (IS)	kg/hr	0	0	0		8	8	0	0		0	0
Ca(OH)2 (IS)	kg/hr											
Others (Insoluble Solids)	kg/hr	9	1	0		2,033	1,992	41	10		10	30
Enthalpy Flow (millions)	Kcal/hr	-489.6	-84.3	-7.9	-111.5	-969.8	-330.6	-649.5	-162.4	-308.0	-581.9	-487.1
Average Density	g/ml	0.979	0.979	0.979	0.900	1.013	1.157	0.999	0.999	0.998	0.979	0.999

Heat Stream No.	M M kcal/hr		Work Stream No.	kW
			WC601	63.13
			WP630	41.21
			WS601	992.08
			WT630	4.74

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	M at Const.
A-630	Recycled Water Tank Agitator	1	0	Fixed-Prop	CS
C-601	Lignin Wet Cake Screw	1	0	Screw	CS
P-630	Recycled Water Pump	1	1	Centrifugal	CS
S-601	Beer Column Bottoms Centrifuge	3	0	Centrifugal	316SS
T-630	Recycled Water Tank	1	0	Flat-BTM -Storage	CS

VER	DESCRIPTION	DATE
A	SUBCONTRACTOR UPDATE	4/98
B	BASECASE UPDATE	9/98
C	WWT UPDATE	11/98
D	DESIGN REPORT	2/99
		LL 2/24/99

NATIONAL RENEWABLE ENERGY LABORATORY

Biotechnology Center For Fuels And Chemicals

SECTION A600
LIGNIN SEPARATION & RECYCLE

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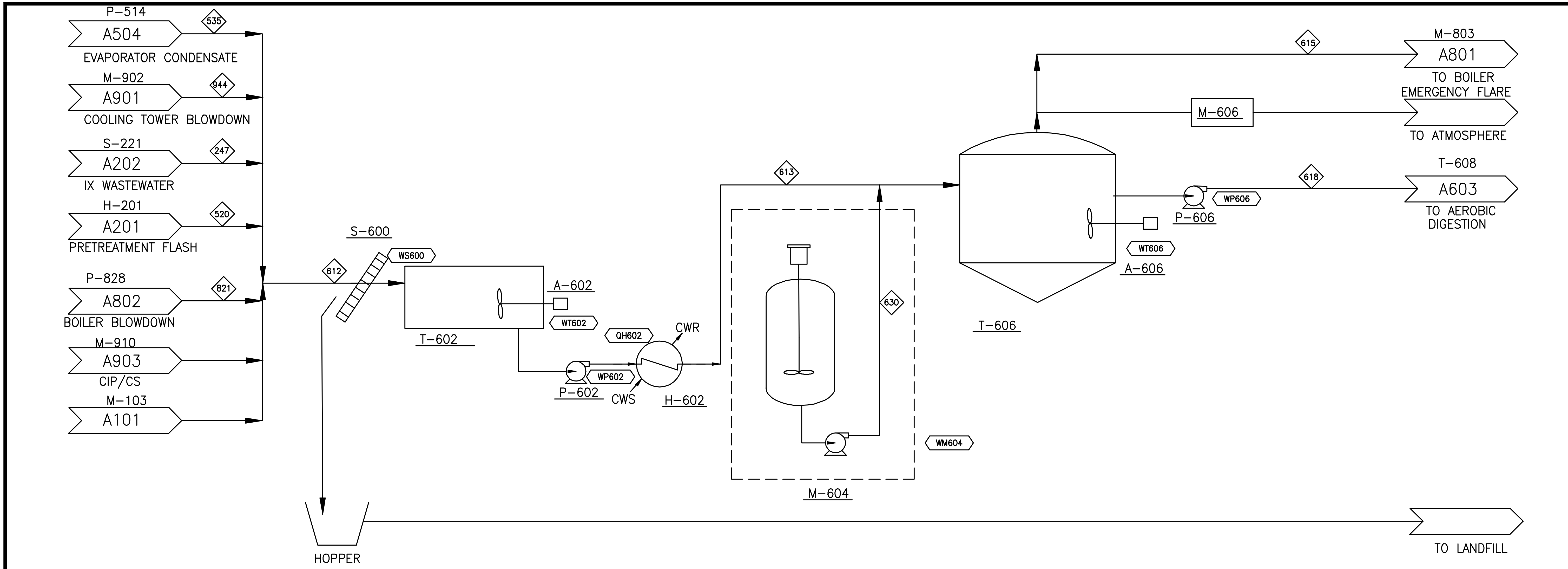


COMPONENT	UNITS	247	520	535	612	613	615	618	630	821	944
Total Flow	kg/hr	91,967	45,124	13,834	174,143	174,143	0	171,786	225	6,613	16,605
Insoluble Solids	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
Soluble Solids	%	4.8%	0.1%	0.3%	2.6%	2.6%	0.0%	0.2%	0.0%	0.0%	0.0%
Temperature	C	40	100	73	79	35		35	20	321	28
Pressure	atm	3.00	1.00	2.00	2.00	2.00		1.00	1.00	112.62	1.00
Vapor Fraction		0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ethanol	kg/hr		34	13	47	47		3			
Water	kg/hr	87,291	43,810	13,684	168,003	168,003		170,526		6,613	16,605
Glucose (SS)	kg/hr										
Xylose (SS)	kg/hr		0	0	0	0		0			
Arabinose (SS)	kg/hr		0	0	0	0					
Other Sugars (SS)	kg/hr										
Cellobiose (SS)	kg/hr										
Glucose Oligomers (SS)	kg/hr										
Xylose Oligomers (SS)	kg/hr		0	0	0	0					
Other Oligomers (SS)	kg/hr										
Corn Steep Liquor (SS)	kg/hr		31	38	70	70		70			
(NH4)2SO4 (SS)	kg/hr	917			917	917					
NH4Acetate (SS)	kg/hr	3,515			3,515	3,515		246			
Others (Soluble Solids)	kg/hr										
Acetic Acid	kg/hr		261	41	302	302		21			
Sulfuric Acid	kg/hr		0	0	0	0					
Furfural	kg/hr		737	41	777	777		54			
HM F	kg/hr		248	14	262	262		18			
Carbon Dioxide	kg/hr							45			
M ethane	kg/hr							2			
Oxygen	kg/hr										
Nitrogen	kg/hr										
Ammonia	kg/hr	7	0	0	7	7		7			
NH4OH	kg/hr	237			237	237		204			
Others	kg/hr		3	4	6	6		424	225		
Cellulose (IS)	kg/hr										
Xylan (IS)	kg/hr										
Arabinan (IS)	kg/hr										
Other Sugar Polymers (IS)	kg/hr										
Cellulase (IS)	kg/hr										
Biomass (IS)	kg/hr							166			
Zymo (IS)	kg/hr										
Lignin (IS)	kg/hr										
Gypsum (IS)	kg/hr										
Ca(OH)2 (IS)	kg/hr										
Others (Insoluble Solids)	kg/hr										
Enthalpy Flow (millions)	Kcal/hr	-344.7	-162.1	-51.5	-644.0	-651.4		-646.8	-0.9	-22.9	-62.8
Average Density	g/ml	0.915	0.009	0.946	0.910	0.949		0.982	0.998	0.665	0.991

Heat Stream No.	M M kcal/hr
QH602	7.37

Work Stream No.	kW
WM604	7.42
WP602	41.91
WP606	39.97
WS600	0.74
WT602	24.81
WT606	120.86

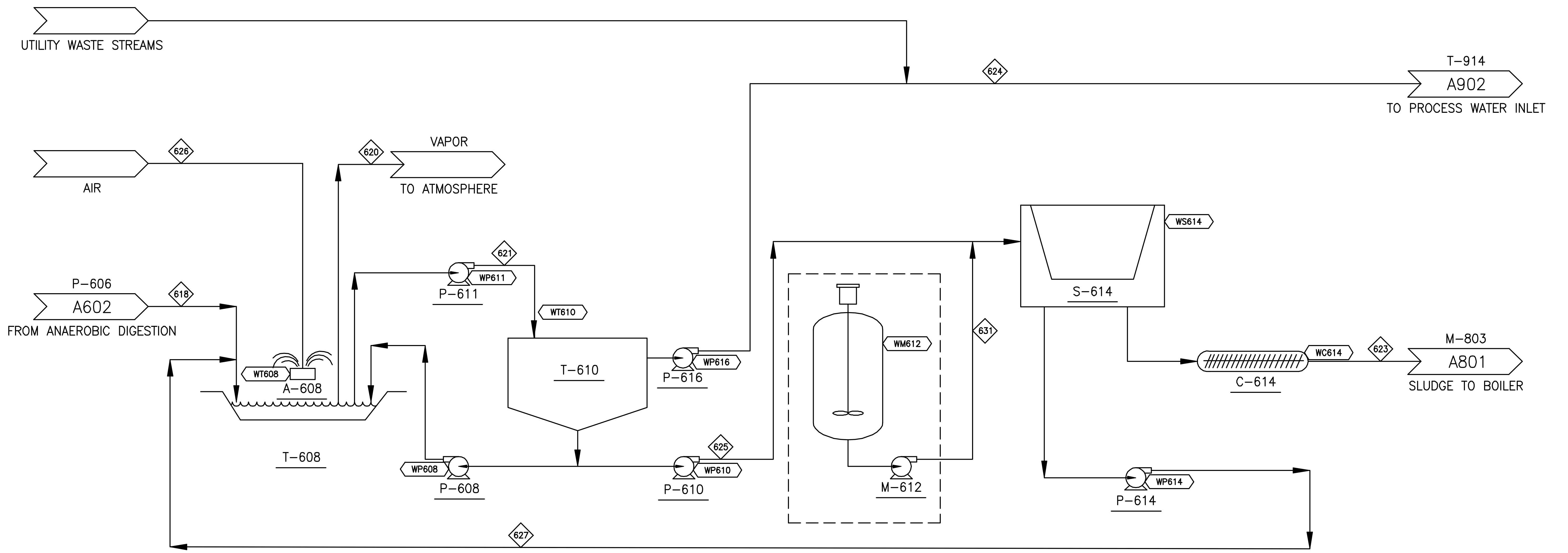
Eq. No.	Equipment Name	Req.	Spare	Equipment Type	M at Const.
A-602	Equalization Basin Agitator	1	0	Fixed-Prop	SS
A-606	Anaerobic Agitator	4	0	Fixed-Prop	SS
H-602	Anaerobic Digestor Feed Cooler	1	0	Shell-Tube	SS316;CS
M -604	Nutrient Feed System	1	0	Package	CS
M -606	Biogas Emergency Flare	1	0	M iscellaneous	SS
P-602	Anaerobic Reactor Feed Pump	1	1	Centrifugal	CS
P-606	Aerobic Digestor Feed Pump	1	1	Centrifugal	CS
S-600	Bar Screen	1	0	Screen	CS
T-602	Equalization Basin	1	0	Flat-BTM-Storage	CONCRETE
T-606	Anaerobic Digestor	4	0	Flat-BTM-Storage	EPOXY-LINED

VER	DESCRIPTION	DATE
A	SUBCONTRACTOR UPDATE	4/98
B	BASECASE UPDATE	9/98
C	WWT UPDATE	11/98
D	DESIGN REPORT	2/99
		LL 2/24/99

NREL NATIONAL RENEWABLE ENERGY LABORATORY
Biotechnology Center For Fuels And Chemicals

SECTION A600
ANAEROBIC DIGESTION

r9901f.xls | PFD–P100–A602 | D



COMPONENT	UNITS	618	620	621	623	624	625	626	627	631
Total Flow	kg/hr	171,786	152,740	173,428	897	168,058	5,371	149,908	4,475	1
Insoluble Solids	%	0.1%	0.0%	0.2%	30.0%	0.0%	5.0%	0.0%	0.0%	0.0%
Soluble Solids	%	0.2%	0.0%	0.1%	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%
Temperature	C	35	21	21	21	21	21	20	21	20
Pressure	atm	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Vapor Fraction		0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Ethanol	kg/hr	3	0	0	0	0	0		0	
Water	kg/hr	170,526	2,379	172,759	626	167,669	5,090		4,464	
Glucose (SS)	kg/hr									
Xylose (SS)	kg/hr	0								
Arabinose (SS)	kg/hr									
Other Sugars (SS)	kg/hr									
Cellobiose (SS)	kg/hr									
Glucose Oligomers (SS)	kg/hr									
Xylose Oligomers (SS)	kg/hr									
Other Oligomers (SS)	kg/hr									
Corn Steep Liquor (SS)	kg/hr	70	1	71	0	69	2		2	
(NH4)2SO4 (SS)	kg/hr									
NH4Acetate (SS)	kg/hr	246		25	0	24	1		1	
Others (Soluble Solids)	kg/hr									
Acetic Acid	kg/hr	21	0	2	0	2	0		0	
Sulfuric Acid	kg/hr									
Furfural	kg/hr	54	1	5	0	4	0		0	
HMF	kg/hr	18	0	2	0	1	0		0	
Carbon Dioxide	kg/hr	45	333	0	0	0	0		0	
Methane	kg/hr	2	2	0	0	0	0		0	
Oxygen	kg/hr		31,222	1	0	1	0	31,481	0	
Nitrogen	kg/hr		118,452	3	0	3	0	118,427	0	
Ammonia	kg/hr	7	1	6	0	5	0		0	
NH4OH	kg/hr	204	170	35	0	34	1		1	
Others	kg/hr	424	179	252	1	244	7		7	1
Cellulose (IS)	kg/hr									
Xylan (IS)	kg/hr									
Arabinan (IS)	kg/hr									
Other Sugar Polymers (IS)	kg/hr									
Cellulase (IS)	kg/hr									
Biomass (IS)	kg/hr	166		269	269		269			
Zymo (IS)	kg/hr									
Lignin (IS)	kg/hr									
Gypsum (IS)	kg/hr									
Ca(OH)2 (IS)	kg/hr									
Others (Insoluble Solids)	kg/hr									
Enthalpy Flow (millions)	Kcal/hr	-646.8	-8.6	-656.5	-2.6	-636.9	-19.6	-0.2	-17.0	0.0
Average Density	g/ml	0.982	0.001	0.998	1.148	0.997	1.022	0.001	0.997	0.998

Heat Stream No.	MM kcal/hr		Work Stream No.	kW
			WC614	5.13
			WM612	3.73
			WP608	1.21
			WP610	0.71
			WP611	39.72
			WP614	1.03
			WP616	38.51
			WS614	20.69
			WT608	605.87
			WT610	3.71

Eq. No.	Equipment Name	Req.	Spare	Equipment Type	Mat Const.
A-608	Aerobic Lagoon Agitators	16	0	SURFACE-AERATOR	CS
C-614	Aerobic Sludge Screw	1	0	SCREW	CS
M-612	Filter Precoat System	1	0	MISCELLANEOUS	CS
P-608	Aerobic Sludge Recycle Pump	1	0	SLURRY	SS316
P-610	Aerobic Sludge Pump	1	0	SLURRY	SS316
P-611	Aerobic Digestion Outlet Pump	1	1	CENTRIFUGAL	CS
P-614	Sludge Filtrate Recycle Pump	1	1	CENTRIFUGAL	CS
P-616	Treated Water Pump	1	1	CENTRIFUGAL	CS
S-614	Belt Filter Press	1	0	FILTER-PRESS	0
T-608	Aerobic Digestor	1	0	LINED-PIT	POLYMER LINED
T-610	Clarifier	1	0	CLARIFIER	CONCRETE

VER	DESCRIPTION	DATE
A	SUBCONTRACTOR UPDATE	4/98
B	BASECASE UPDATE	9/98
C	WWT UPDATE	11/98
D	DESIGN REPORT	2/99
		LL 2/24/99

NATIONAL RENEWABLE ENERGY LABORATORY

Biotechnology Center For Fuels And Chemicals

SECTION A600
AEROBIC DIGESTION

PFD-P100-A603 D

Appendix J

Waste Water Analysis Results

EVERGREEN ANALYTICAL, Inc.

4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

Analysis Report

Co-current
Enzyme

Client Sample I.D. : BF772014-P04
Lab Sample Number : 98-1609-01
Date Sampled : 04/23/98
Date Received : 04/23/98

Client Project I.D. : Waste Water Verification
Lab Project Number : 98-1609
Matrix : Liquid Waste

Analysis	Method	Date Prepared	Date Analyzed	Result	Units
Total Suspended Solids	Standard Method 2540 D	04/27/98	04/27/98	11.0	mg/L
Biochemical Oxygen Demand	EPA 405.1	04/24/98	04/29/98	* ~~63400~~ 13,400 per N. Nigel	mgO_2/L
Chemical Oxygen Demand	Hach Method 8000	04/24/98	04/24/98	27000 (2.7%)	mgO_2/L
Settleable Solids	Standard Method 2540 F	04/24/98	04/24/98	<0.1	ml/L

* Estimated Value due to underdilution

$\% \frac{BOD}{COD} = 0.4963$

Vicki - got your message. Evergreen did re-run that sample. The BOD was 13400 mgO_2/L
Call if you have questions!
Nick

R.P. Musil II
Analyst

Approved

EVERGREEN ANALYTICAL, Inc.

4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

Analysis Report

Counter-curren
MR 2000

Client Sample I.D. : TiO2 Treatment
Lab Sample Number : 98-1593-02
Date Sampled : 04/22/98
Date Received : 04/22/98

Client Project I.D. : Waste Water Verification
Lab Project Number : 98-1593
Matrix : Liquid Waste

Analysis	Method	Date Prepared	Date Analyzed	Result	Units
Total Suspended Solids	Standard Method 2540 D	04/27/98	04/27/98	470	mg/L
Biochemical Oxygen Demand	EPA 405.1	04/23/98	04/28/98	29400	mgO_2/L
Chemical Oxygen Demand	Hach Method 8000	04/24/98	04/24/98	54000 (5.4%)	mgO_2/L
Settleable Solids	Standard Method 2540 F	04/24/98	04/24/98	<0.1	ml/L

$\frac{\text{\% BOD}}{\text{COD}} = 0.544$

R.P. Musil III
Analyst

Approved

EVERGREEN ANALYTICAL, Inc.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

Softwood

Analysis Report

Client Sample I.D.	: Spent Broth MTX 7F	Client Project ID	: Waste Water Verification
Lab Sample Number	: 98-1697-01	Lab Project Number	: 98-1697
Date Sampled	: 4/30/98	Matrix	: Liquid Waste
Date Received	: 4/30/98		

Analysis	Method	Date Prepared	Date Analyzed	Result	Units
Total Suspended Solids	Standard Method 2540 D	5/4/98	5/4/98	953	mg/L
Biochemical Oxygen Demand	EPA 405.1	5/1/98	5/6/98	18300 (1.8%)	mgO_2/L
Chemical Oxygen Demand	Hach Method 8000	5/6/98	5/6/98	37000 (3.7%)	mgO_2/L
Settleable Solids	Standard Method 2540 F	5/7/98	5/7/98	0.47	ml/L

% $\frac{BOD}{COD}$ = 0.4946

Post-it® Fax Note 7671	Date 5/8	# of pages ▶ 1
To Nick Nagel	From Mack Mensik	
Co./Dept. NREL	Co.	
Phone #	Phone #	
Fax #	Fax #	

Analyst

Approved

EVERGREEN ANALYTICAL, Inc.
4036 Youngfield St. Wheat Ridge, CO 80033
(303) 425-6021

Counter-current Control

Analysis Report

Client Sample I.D.	: Control	Client Project I.D.	: Waste Water Verification
Lab Sample Number	: 98-1593-01	Lab Project Number	: 98-1593
Date Sampled	: 04/22/98	Matrix	: Liquid Waste
Date Received	: 04/22/98		

Analysis	Method	Date Prepared	Date Analyzed	Result	Units
Total Suspended Solids	Standard Method 2540 D	04/27/98	04/27/98	630	mg/L
Biochemical Oxygen Demand	EPA 405.1	04/23/98	04/28/98	28800	mgO_2/L
Chemical Oxygen Demand	Hach Method 8000	04/24/98	04/24/98	52000 (5.2%)	mgO_2/L
Settleable Solids	Standard Method 2540 F	04/24/98	04/24/98	<0.1	ml/L

% $\frac{BOD}{COD}$ = 0.5538

Post-it® Fax Note 7671	Date 4/29 # of pages 2
To Nick Nagle	From Mark Mensik
Co./Dept. NREL	Co.
Phone #	Phone #
Fax #	Fax #

R.P. Musil III
Analyst

Approved

PINNACLE
Biotechnologies International, Inc.

July 1, 1998

Nick Nagle
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401

Dear Nick,

This letter report and the accompanying invoice serves as the conclusion of activities under NREL procurement P.O. #160809. Sample characterization data were summarized in a previous letter report. Presently, the anaerobic fermentation data and conclusions are described.

The Anaerobic Fermentation Bioassay

It is important to note at the outset that the BMP assay may be useful in determining the potential level of bioconversion which may be possible for a test substrate. This assay may also give indications of a potential for a test substrate to cause inhibition of the anaerobic consortium which would limit or preclude conversion of the test substrate at least under anaerobic conditions. However, the BMP assay is always viewed as a rough cut analysis, with evaluation of continuous anaerobic digestion systems as a natural next step to provide better process data on rates and yields prior to engineering and costing commercial systems. The BMP assay may also be used to determine the effectiveness of treatments aimed at reducing sample toxicity or to improve the potential conversion rates and yields. Several important issues regarding the anaerobic fermentation studies (biochemical methane potential [BMP] assay) must be discussed prior to the interpretation of the data.

The Anaerobic Culture. A robust, diverse, anaerobic culture from a reliable, defined source is important to establishing the best fermentation analysis data. PINNACLE uses anaerobic cultures from anaerobic digesters at local municipal sewage treatment plants as assay and starter cultures as these cultures; 1) see a diverse mixture of organic wastes and therefore the microbial populations are diverse in biodegradative capabilities, 2) receive substantial macro and micro-nutrients and therefore are not operating under limiting or inhibitory conditions, and 3) are readily available and may be further obtained in large quantities for starting large scale applied systems once sufficient testing data is obtained.
The quantity of test culture used in the anaerobic fermentation assays is maximized to ensure rapid biodegradative results and to reduce the potential negative effects of dilution on the activity

of the culture.

Negative Control. A set of three negative controls were used during anaerobic fermentation studies to account for biogas production due to intrinsic organic matter contained in the anaerobic culture. It should be noted that any active culture used in fermentation tests will produce biogas from intrinsic organic matter unless the culture is first "washed" to remove this material first. For anaerobic fermentation studies, culture washing is detrimental to culture viability due to the potential to introduce oxygen or removal of complex macro and micro-nutrients. Without removing the intrinsic organics contained in the anaerobic culture, it is possible that an added test sample will negatively or positively affect the conversion of the intrinsic culture organics and therefore the background biogas production.

Positive Control. Generally, a positive control is selected which is similar to the composition of the test samples and which can serve as a check on the biodegradative capacity of the anaerobic culture used. The positive control is prepared at similar pH and organic loading to the test samples.

Anaerobic Fermentation Studies
Test Samples. Test sample characterizations were described in a previous letter report and indicated that samples MTX 7F, TiO2, and the Control Hydrolyzate were comparable in mass percent volatile solids (organic content) while sample BF 772014 was nearly 50% more dilute. The pH of all test samples were considerably below pH 7.0 and required adjustment with potassium hydroxide prior to fermentation studies. The analysis of chemical oxygen demand (COD), a measure of oxidizable carbon in the sample, indicated samples TiO2 and the Control Hydrolyzate were similar and the highest of the samples while BF 772014 was the lowest.

Positive Control. For the positive control, a solution of protein hydrolyzate (BactoPeptone, Difco) was used. The use of a protein hydrolyzate sample was envisioned to be relatively close to the composition of the ethanol hydrolyzate samples. The mass percent volatile solids and COD values for the positive control sample were only slightly greater than samples TiO2 and the Control Hydrolyzate.

Pre-Incubation and Startup. Anaerobic fermentation assays were initiated following incubation of the assay bottles for almost four days in order to reduce the background biogas production derived from the intrinsic organics in the anaerobic culture. A single volumetric loading was used (5%) which resulted in varying organic loadings for the different test samples from 1.41 to 2.87 grams of COD per liter of culture due to their individual concentrations.

Results. Immediate and strong biogas production was determined for all test samples as detailed in Figure 1. All samples also demonstrated the majority of the biogas production, hence the sample organic conversion, was complete within 5 to 10 days. The overall level of anaerobic bioconversion for each test sample is shown in Figure 2 based on the individual sample COD loading. A theoretical yield of 350 mL of methane per gram of COD added represents 100% conversion (Owen and McCarty, 1964). Anaerobic conversion data is shown in Table 1, below for the test samples after 26 days of incubation.

Table 1. Anaerobic Fermentation Data and Final Analyses (26 d)

Assay	BF 772014	MTX 7F	TiO2	Control Hyd.	Bacto Peptone
COD Loading (gCOD/bottle)	0.141	0.174	0.279	0.272	0.287
Theoretical CH4 Yield (mL)	49.35	60.90	97.65	95.20	100.45
Actual CH4 Yield (mL)	36.07	75.16	35.39	76.93	83.01
% Anaerobic Conversion	73.09	123.42	36.24	80.81	82.64
Final Biogas Methane (%)	61.40	61.86	64.56	61.43	64.98
Final pH	7.23	7.22	7.24	7.24	7.36

In general, the data indicates that the positive control (BactoPeptone), the Control Hydrolyzate, and BF 772014 resulted in similar levels of bioconversion (70% to 80%). If these samples were to be further incubated to 90 days, the final level of anaerobic conversion based on COD loading would most likely range from 90% to 100% of the theoretical. This slow approach to near complete digestion during the extended incubation period (final 60 days of a 90 day test) represents the adaptation of the anaerobic culture to minor, less common organics in the test samples.

The results found for the positive control, the Control Hydrolyzate and BF 772014 are characteristic of organic wastes which are eminently biodegradable. Test sample TiO2 demonstrated limited biogas production indicating that organics in the sample were only partly biodegradable.

BMP data for NREL sample MTX 7F indicated greater than 100% conversion to the methane endproduct. This may be explained as either inaccurate COD analysis or active enzymes contained in the sample which are effective in converting recalcitrant intrinsic organics (i.e., polymers) of the seed culture. Table 2. compares initial and final COD analysis for all four NREL test samples and validates the relative accuracy of the assay.

Table 2. Re-Evaluation of NREL Test Sample COD Values

Assay	BF 772014	MTX 7F	TiO2	Control Hyd.
Primary COD Assay (mg/L)	28,267	34,800	55,800	54,400
Secondary COD Assay (mg/L)	26,330	32,330	53,330	55,660
Difference (%)	-6.85	-7.10	-4.43	+2.32

As the accuracy of the test sample COD values are assured, the only plausibly explanation is sample MTX 7F contained active hydrolytic enzymes which served to hydrolyze recalcitrant organics contained in the starter culture. Methods to test this theory and determine the true nature of the anaerobic biodegradation potential for this sample may include a thermal treatment of the sample to inactivate enzymes followed by conducting another BMP assay. In addition, the test sample could be analyzed by standard method for hydrolyzing enzyme activity.

Conclusion

All samples tested demonstrated immediate and strong biogas production. None of the samples tested demonstrated toxicity to the anaerobic culture. The positive control demonstrated predicted effectiveness of the anaerobic starter culture. NREL samples BF 772014 and the Control Hydrolyzate demonstrated conversions similar to that of the positive control and may therefore be considered amenable to anaerobic treatment. NREL sample TiO2 demonstrated reduced conversion effectiveness which is likely due to some level of non-biodegradable organics in the sample. The excessive biogas production resulting in assays performed using NREL sample MTX 7F indicates that additional testing as described above is required to accurately predict the level of conversion possible.

While this data may be used to predict approximate fuel gas production which may result from treating large volumes of the respective organic steams using anaerobic digestion systems, in order to accurately engineer commercial-scale anaerobic systems, additional data from applied, longer-term operation of continuous anaerobic digestion systems should be obtained.

PINNACLE
Biotechnologies International, Inc.

Nick Nagle
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401

Dear Nick,

The four NREL samples received from you were stored under refrigeration until being transferred by cooler to PINNACLE's Research, Development and Testing Center in Stanton, California for analysis and fermentation studies.

Rather than using Avecel as the positive control for these studies, a soluble substrate was used which more closely matches the NREL samples. The positive control substrate used was a Bacto Peptone solution at 4.5% w/v in distilled water. The NREL samples were analyzed on delivery PINNACLE's Testing Center. Total solids (%TS), volatile solids (%VS), and ash analyses were performed in triplicate. Analysis of sample pH were performed after a 2-point standardization of the combination pH probe.

Table 1. Sample Analysis Upon Receipt

Assay	BF 772014	MTX 7F	TiO2	Control Hyd.	Bacto Peptone
% Total Solids	2.73	4.49	5.56	5.20	5.67
% Volatile Solids	87.44	89.86	74.04	82.33	95.67
Mass % Volatile Solids	2.39	4.03	4.12	4.28	5.42
pH	5.39	4.93	5.24	5.36	7.08

As the NREL samples were considerably lower than the pH 7.0 necessary to perform the anaerobic digestibility analysis, they were adjusted to neutrality using a 5% w/v solution of KOH. A 50 mL aliquot of each sample was transferred to a small beaker. The sample was mixed using a magnetic stirrer and the pH monitored during KOH addition. The samples were then analyzed for Chemical Oxygen Demand (COD) using the HACH High Range Plus COD tube assay. All COD assays were performed in triplicate as detailed in Table 2.

1667 Cole Blvd., Suite 400, Golden, CO 80401 Phone (303) 235-0613 Fax (303) 235-0603

Table 2. Sample pH Adjustment and COD Analysis

Assay	BF 772014	MTX 7F	TiO2	Control Hyd.
Initial pH	5.39	4.93	5.24	5.36
mL KOH Added	0.56	1.22	1.11	0.8
Dilution Factor	0.9889	0.9762	0.9783	0.9843
Final pH	7.12	7.08	7.13	7.14
COD (mg/L)	28,267	34,800	55,800	54,400

For comparison, the COD level of the Bacto Peptone positive control was 57,400 mg/L.

Anaerobic Digestibility Assays

The Biochemical Methane Potential (BMP) assay was used to address the biodegradability or toxicity of the NREL samples. The BMP assay employed a mesophilic anaerobic culture obtained from the Terminal Island Sewage Treatment Plant, Terminal Island, CA. This anaerobic culture was assayed prior to use as detailed in Table 3.

Table 3. Analysis of the Terminal Island Anaerobic Culture Used in BMP Assays

Assay	Value
Total Solids	3.11%
Volatile Solids	62.53%
Ash	37.47%
pH	7.43

The BMP assays were prepared in triplicate using serum bottles with a total volume of 162 mL. Using a 25 mL pipette, 100 mL (± 1.8 mL) of active anaerobic culture was transferred to each serum bottle. The headspace of each serum bottle was then flushed with UHP nitrogen for 1-min. prior to closing the bottles with a rubber stopper and an aluminum crimp cap. The serum bottles were incubated at 37°C with shaking (200 rpm) using a Lab-Line Orbit Environ-Shaker.

The serum bottles were incubated for a period of almost 4 days prior to commencing the BMP assay in order to reduce background biogas production from intrinsic organic matter contained in the anaerobic sludge culture. In order to reduce the negative effects of dilution on the BMP anaerobic culture, a standard 5 mL addition of each test substrate was used. This represented roughly a 5% dilution of the anaerobic culture. The actual organic loadings and theoretical methane potential for each substrate varied as per its relative composition as described below in Table 4.

Table 4. BMP Organic Loadings

Sample	Volume Added	Organic Loading		Theoretical Methane Yield (mL)**
		gVS/bottle*	gCOD/bottle	
Bacto Peptone	5 mL	0.271	0.287	100.45
BF 772014	5 mL	0.118	0.141	49.35
MTX 7F	5 mL	0.197	0.174	60.90
TiO2	5 mL	0.202	0.279	97.65
Control Hydrolyz.	5 mL	0.211	0.272	95.20

* Volatile solids loading corrected for sample dilution during pH adjustment.
** Theoretical methane yields based on COD loading using a yield of 350 mL CH_4 per gram COD added (Owen and McCarty, 1964).

Appendix K

Comparison of CH4 Generation

in WWT Models

National Renewable Energy Laboratory

Memo

To: R. Wooley

From: K. Kadam

Date: September 21, 1998

Subject: Comparison of CH_4 Generation in WWT Models

There is a discrepancy between methane yields from the old Aspen model and that from the new model incorporating the latest WWT as designed by Merrick & Co. Hence, the assumptions of various WWT models regarding biomethanation were compared.

The current biomethanation basis is from the Chem Systems report ("Biomass to Ethanol Process Evaluation," December 1994), page III-31. The original basis for COD-to-CH_4 conversion had come from the CH2MHill report ("Full Fuel Cycle Evaluation of Biomass to Ethanol: Wastewater Treatment System Performance," DEN/197/R/012.51/1, December 10, 1991) page 13, Table 4. These bases are summarized in Table 1. Merrick & Co.'s basis is 0.35 L/g COD, with a molar ratio of CH_4:CO_2::0.75:0.25; however, the numbers for Merrick in Table 1 are calculated from the Aspen output.

Table 1. Conversion of COD to CH_4, CO_2 and Cell Mass

	CH_4, g/g COD	CO_2, g/g COD	Cell Mass, g/g COD
Previous bases			
Chem Systems	0.5600	0.2400	0.2000
CH2MHill	0.2413	0.1607	0.0553
Current estimated bases			
	New model with syrup to WWT[1]		
Merrick	0.1970	0.1801	0.0306
	New model with syrup to burner/off the sheet[2]		
Merrick	0.2719	0.2486	0.0355

[1]Model no. R9808N
[2]Model no. R9808N1

Table 2. CH_4, CO_2 and Cell Mass Yields for Various Cases (2000 tpd Enzyme Process)

	CH_4, kg/h	CO_2, kg/h	Cell Mass, kg/h	Total, kg/h
	Old model[1]			
Chem Systems	7237.1	3101.6	2584.7	12923.4
CH2MHill	3118.4	2076.8	714.7	5909.9
	New model with syrup to WWT[2]			
Chem Systems	6566.9	2814.4	2345.3	11726.6
CH2MHill	2829.6	1884.5	648.5	5362.6
Merrick	2310.2	2112.5	359.0	4781.6
	New model with syrup to burner/off the sheet[3]			
Chem Systems	2515.1	1077.9	898.3	4491.3
CH2MHill	1083.7	721.7	248.4	2053.9
Merrick	1221.2	1116.7	159.6	2497.4

[1]Model no. W9804H
[2]Model no. R9808N
[3]Model no. R9808N1

Table 2 shows that the methane yields based on the Chem Systems report are off by a factor of 2–3. This is because the Chem Systems methane yield does not seem to be based on any field experience but rather is calculated from erroneous assumptions. The CH2MHill and Merrick bases give similar results. Hence, the Merrick WWT model seems to be a reasonable approximation of a real-life WWT system for methane yields. However, the big difference in COD-to-CH_4 yields for the two Merrick cases should be explained.

cc: M. Ruth, K. Ibsen